DEGREES OF CHANGE

Steps Towards an Ontario Global Warming Strategy

Prepared for:

Ontario Ministry of Energy
Ontario Ministry of the Environment

by:

Ontario Global Warming Coalition

Ontario

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Ontario Ministry of Energy
and the
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Canadian Environmental Law Association
Energy Action Council of Toronto
Friends of the Earth
Greenpeace
National Energy Conservation Association
Northwatch
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FOREWORD

This report, *Degrees of Change: Steps Towards an Ontario Global Warming Strategy*, was commissioned by the Ontario Ministries of Energy and Environment as part of a wide-ranging consultative effort to develop policy on the global warming issue.

The report is an advocacy document which represents the analysis and judgment of a ten-member team of environmental groups, the Ontario Global Warming Coalition. Prompted by convincing evidence that greenhouse gas emissions represent an impending threat to the natural environment, the report argues that significant economic, political, and social changes are required in Ontario to help reverse the threat of global warming.

Underlying the report's conclusions are optimistic assumptions about the economic and technological potential of measures to avert future environmental damage in Ontario. These assumptions may be justified in the face of scientific warnings which tell us that the way we live in Ontario—and the biological foundation for life itself—are already imperiled by global warming.

It is not a question of whether dramatic change is realistic. Dramatic changes in our climate are already beginning to reshape our future. The question which confronts us is: do we change by default or by design?

The report is a welcome contribution to the public discussion on developing a strategy on global warming. The Global Warming Coalition has provided a thoughtful and challenging set of insights.

Sincerely,

Jenny Carter,
Minister of Energy

Ruth Grier,
Minister of the Environment

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NOTE ON ENERGY CONVERSION

Different fuels and forms of energy often are measured in different units. Electricity is counted in kilowatt-hours (kWh), for instance, coal in British thermal units (Btu), and natural gas in cubic feet (ft^3). For convenience and purposes of comparison, a common unit of energy is mostly used in this report—the "joule". Hence, the energy used for a house is described in units of gigajoules (GJ) per household, or billion joules, and includes an inventory of electricity, natural gas, and oil consumed by the household.

Equivalency is as follows:
1 watt-hour = 1 joule/second x 3,600 seconds or 3,600 joules
1 kWh = 3,600,000 joules or .0036 gigajoules (GJ)
or
1 GJ = 278 kWh
1 PJ = 277,777,777 kWh

The prefixes used in this report include the following:

Prefix	*Symbol*	*Power*	*Number*
kilo	k	10^3	thousand
mega	M	10^6	million
giga	G	10^9	billion
tera	T	10^{12}	trillion
peta	P	10^{15}	quadrillion

For example, the coal-fired generating units at Ontario Hydro's Nanticoke power plant, rated at 542 MW, each typically generate 4,300,000,000 kWh annually operating at 90 percent capacity, the equivalent of 15 PJ.

Another example: the average Ontario house uses 140 GJ or the equivalent of 38,700 kWh annually.

CHAPTER 1—INTRODUCTION AND OVERVIEW

> "Humanity is conducting an unintended, uncontrolled, globally pervasive experiment whose ultimate consequences could be second only to a global nuclear war."
>
> Final statement of the Toronto Conference on *"The Changing Atmosphere: Implications for Global Security"* (June 1988)

1.0 Background

In March, 1990, the Ontario government released *Global Warming: Towards a Strategy for Ontario*, a Cabinet document which proposed that the province—as a first step in its effort to address the problem of global warming—reduce emissions of greenhouse gases, especially carbon dioxide (CO_2), so that "levels by the year 2000 are lower than in 1989".[1] The release of the document was accompanied by a workshop for environmental organisations on global warming sponsored by Friends of the Earth and Greenpeace and funded by the Ministry of Energy. The Ontario Global Warming Coalition was founded at the workshop to facilitate further consultation among environmental groups, government, and other stakeholders on the issue.

Environmental groups faulted the government's proposed global warming strategy for several reasons.[2] In their view, the strategy:

- failed to seriously consider a 20 percent cut in carbon dioxide emissions by 2005 from 1988 levels, otherwise known as the "Toronto target";
- outlined only broad, piecemeal strategies that lacked rigorous measures for reductions of carbon dioxide emissions in the residential, commercial, transportation, and industrial sectors;
- did not sufficiently address the market and institutional barriers to energy conservation, renewable energy, and non-utility generation.

The election of a new government has created a pause in the policy-making process and the opportunity to formulate a more deliberate provincial strategy. As a part of the process, the Coalition sought and received support from the Ministries of Energy and Environment to formulate a reasoned case that the "Toronto target" can be achieved in Ontario, if the government pursues a full range of appropriate policy measures. An advisory committee of environmental groups was established to guide the study and, meeting over a period of two months, its members consulted among themselves and with representatives from government to discuss options to reduce CO_2 emissions. Other greenhouse gases are not considered.

This report is the outcome of that process. It offers:

- a survey of the most promising policy measures and technologies to reduce carbon dioxide emissions; estimates of their potential to reduce provincial carbon emissions; and discussion of the primary market and institutional barriers to their achievement, as well as proposal of reforms needed to overcome such barriers, especially in Ontario's regulation of utilities;
- an assessment of the implications of the measures with respect to their cost effectiveness, the institutional changes necessary to successfully implement the measures, and their potential impact on the province's technology base and employment;

- a case study that identifies opportunities for commercializing new natural gas cogeneration technologies in Ontario that could be used to reduce carbon emissions and suggests new policies to help the province capitalize on its global warming strategy by encouraging the growth of new businesses and jobs connected with such technologies.

1.2 What is the Toronto Target?

The "Toronto Target" is a goal that was proposed to governments by scientists assembled at *The Changing Atmosphere Conference* held in Toronto in June, 1988, as an interim step towards a 50-60 percent global reduction needed to stabilize the concentration of CO_2 in the atmosphere.[3]

Since the Toronto conference, the scientific rationale for the 20 percent target has held up under intense scrutiny by national governments, international expert panels, and, most recently, by the world community of meteorologists and energy experts gathered at the Second World Climate Conference held in Geneva in fall, 1990. Many national, provincial, and municipal governments have made commitments to the target, including Toronto (the first city in the world to do so) and neighboring states, New York and Vermont.

The Coalition recognizes that reaching the Toronto target will not be easy. Not only will many fundamental changes be needed in the way energy is produced, distributed, and consumed in the province, but many long-held attitudes will have to give way. Furthermore, the province has little control over some social and economic forces that will affect future CO_2 emission trends. These include population and economic growth. Such growth is near impossible to forecast given the political and economic uncertainties that face Canada in the next few years as it adjusts to the constitutional crisis, to the competitive challenges posed by free trade, and to a world economy buffeted by the significant international capital flows likely to be diverted towards eastern Europe and the Middle East.

One fundamental change that will need to occur, for instance, is the widely held attitude that cheap energy is good for us all. While energy is one of the essential elements of modern industrial society, its increasing use poses one of the gravest risks to natural ecological systems and human health, the Coalition believes. In Canada, the economic assessment of such risks as one of the legitimate functions of the pricing of energy is not yet recognized as an aim of public policy. It will be necessary to do so in order to allow non-polluting forms of energy, such as solar, to compete fairly in the marketplace.

Change is never easy, especially when groups perceive their economic interests to be adversely affected. Home builders may resist stronger energy efficiency provisions in the provincial building code, in part, because they believe the additional costs incurred will put their new homes at a competitive disadvantage with older homes that didn't have to meet such standards. Auto companies may resist any measures to encourage the public to buy more fuel efficient automobiles, because they believe such measures will constrain consumer freedom to buy high performance vehicles, which typically provide higher profit margins than standard vehicles. Oil companies will resist ethanol because it displaces their own fuels and additives. Ontario Hydro may resist the development of the full potential of energy efficiency, parallel generation, and renewable energy because actually realizing such strategies implies a trend toward decentralization at odds with its corporate culture. And governments, faced with opposition from special interests, may balk at formulating new regulations and programmes.

1.3. Recent Scientific Concerns

The year 1990 was a watershed in the evolution of scientific concern about global warming. Global average surface temperatures based on land and marine measurements

reached an all-time high since records began in the middle of the 19th century. According to the British Meteorological Office, the 1990 global mean was 0.39°C above the average during the period 1951 to 1980.[4] The U.S. National Aeronautic and Space Administration (NASA) reported similar results from their global data sources.[5]

The warmth of 1990 was particularly evident over southern Canada, where some regions experienced abnormally high temperatures, particularly in March. (Some regions of Canada, however, experienced cooler weather compared with the 1951 to 1980 period, namely northeastern Canada and the central Arctic.) While temperatures for one year are less significant than trends over a period of years, the fact that 1990 was so warm in the absence of an El Niño event—the periodic appearance of a warm current in the Pacific Ocean that typically warms North America—makes the record breaking temperatures of 1990 more significant than they would otherwise be.

Adding to the concern about temperatures was evidence that snow cover over Northern Hemisphere land masses reached a 19-year low in 1990, nine percent below the 19-year mean, with the most significant decreases occurring during spring.[6] Snow is a key variable in the global heat budget, since it reflects solar radiation back to space. As snow cover decreases in the Northern Hemisphere, land and water masses will absorb more solar radiation and produce more infrared radiation, heating northern countries like Canada up more than their southern neighbors. Indeed, over the past 30 years, winter and spring mean temperatures in northern Ontario have increased as much as 1.5°C, much more than the global average over the same period.[7] (See accompanying Environment Canada maps.)

Also consistent with the belief that a real warming of the climate is occurring is the recent observation that sea ice has thinned by about 15 percent since 1976 over a broad region of the Arctic, although there is no indication yet of a trend in ice area in either hemisphere.[8]

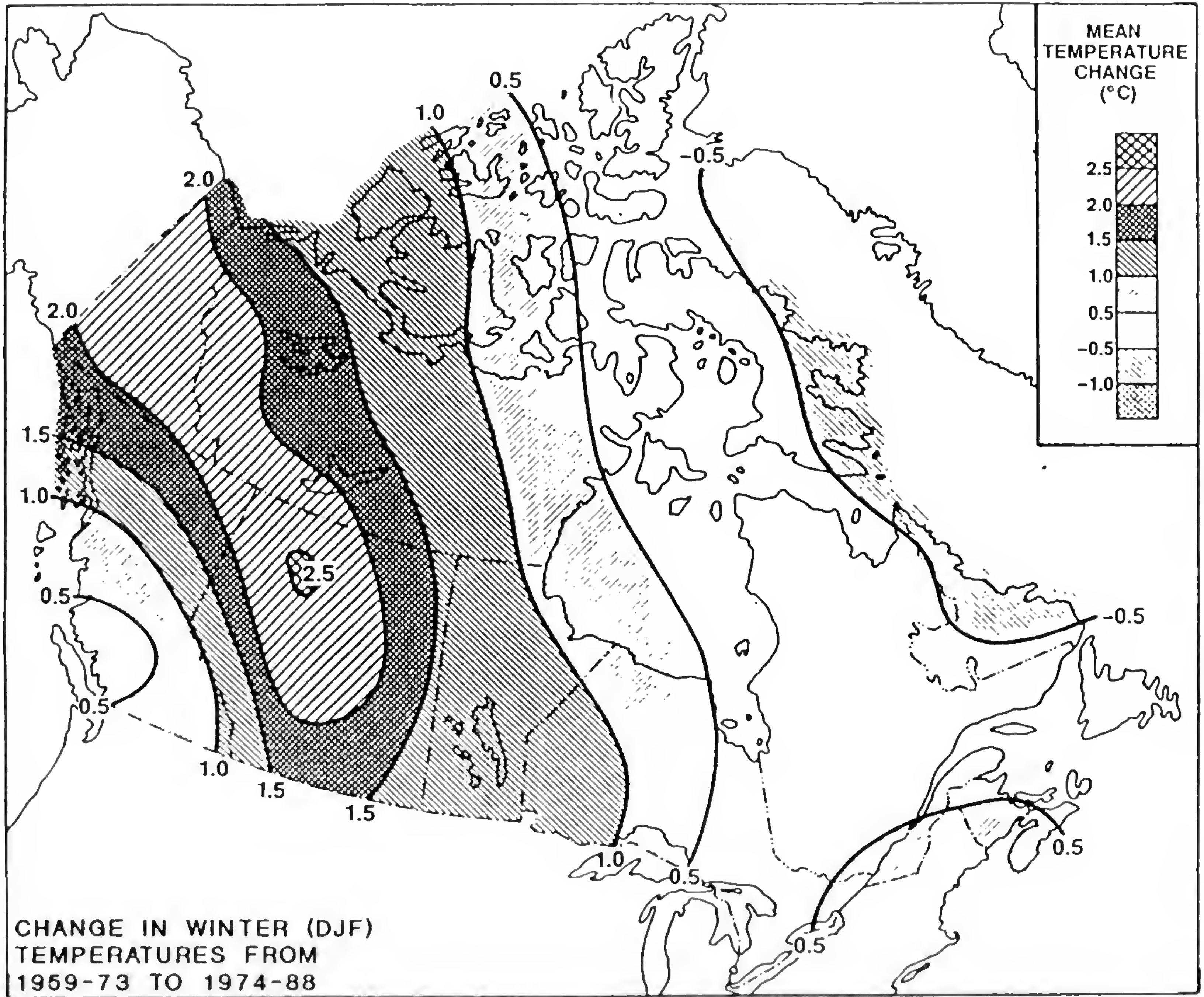
Heightened scientific concern about global warming culminated at the Second World Climate Conference in Geneva in October 1990 in a far reaching consensus about the causes and potential effects of global warming, and possible remedial policies to slow down the rate and reduce the ecological risks of warming. In its final conference statement, scientists and energy experts attending the conference agreed that:

- without action to reduce emissions of greenhouse gases from human activities, global warming is predicted to reach 2-to-5° C over the next century, a rate of change unprecedented in recorded human history, and the warming is expected to be accompanied by a sea level rise of 30-to-100 centimetres;
- a continuous world-wide reduction of net CO_2 emissions of 1-to-2 percent per year would be required to stabilize CO_2 concentrations in the atmosphere by the middle of the next century;
- many studies conclude that technical and cost-effective opportunities exist to reduce CO_2 emissions by at least 20 percent by 2005 in industrialised nations;
- industrialised countries must implement reductions even greater than those required, on average, for the globe as a whole, in order to allow for growth in emissions from developing countries.

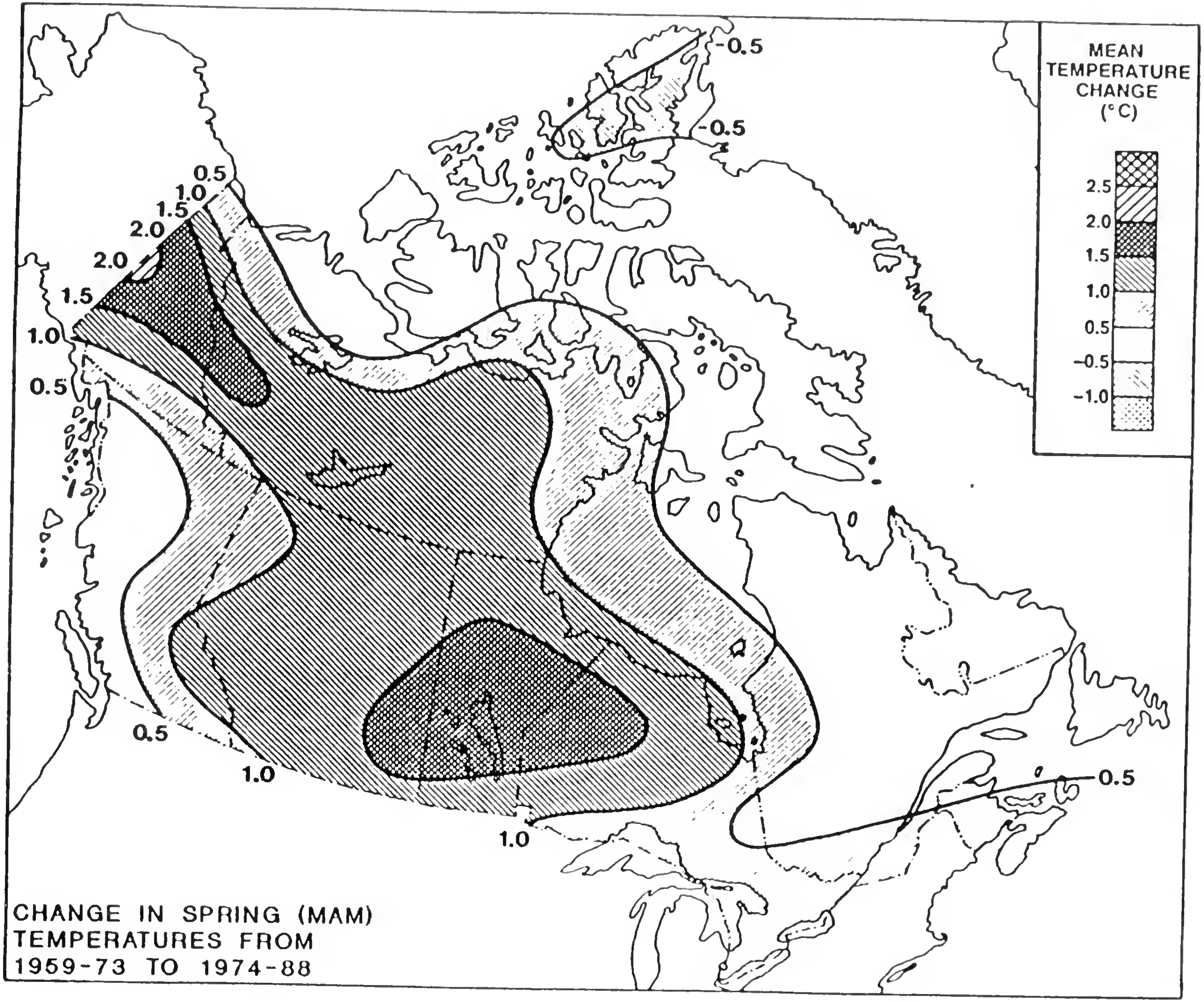
In sum, scientists sent a clear message to industrialised nations: significant emissions reductions must begin now, and cost-effective opportunities are available to make them.

1.4 Rationale for an Ontario Global Warming Strategy

Can and how should Ontario respond to such concerns? The Coalition believes that the Ontario government should make a commitment to reduce emissions of CO_2—the most impor-



CHANGE IN WINTER (DJF) TEMPERATURES FROM 1959-73 TO 1974-88



CHANGE IN SPRING (MAM)
TEMPERATURES FROM
1959-73 TO 1974-88

tant greenhouse gas—by 20 percent from 1988 levels by 2005, as an interim step towards eventual reductions of 50-60 percent by 2010-2020, which are eventually needed to stabilize concentrations of greenhouse gases in the atmosphere.

Such an effort is justified for several reasons. First, Ontario's economy, people, and wilderness areas are likely to be significantly affected by global warming, many in adverse ways, reason enough for the province to undertake a serious CO_2 reduction effort. Second, Ontario's leadership, acting in concert with other local provincial and state governments around the world, can make a difference in spurring national governments to take action. Finally, a major effort to reduce the energy intensity of the province's economy and reduce CO_2 emission over the next 15 years would create important new opportunities for technological and economic advancement, ranging from the production of energy efficient appliances and equipment to the development of new energy supply technologies, such as cogeneration systems.

REGIONAL EFFECTS OF GLOBAL WARMING. How will global warming affect Ontario's economy and natural resources? The regional effects of global temperature changes are difficult to assess because the computer simulations undertaken by climate models are rudimentary and are likely to remain so for many years. While the results of climate modeling, therefore, need to be treated with caution, studies recently commissioned by Environment Canada of the potential regional effects if atmospheric CO_2 doubles suggest that adverse effects may outweigh positive ones in Ontario:

- *Great Lakes*—while the reduction in the mean length of the ice season will increase the marine shipping season, net basin supply from runoff of water from the region's watershed will decline by 10-20 percent which, combined with increased evaporation and greater consumptive uses, will lower lake levels, adversely affecting shipping, wetlands, and hydro capacity at Niagara Falls.[9]

- *Agriculture*—a warmer climate may benefit agriculture in a number of ways, such as an extension of the growing season in northern Ontario and the beneficial response of crops to higher concentrations of atmospheric CO_2, but there is, nevertheless, a risk of significant crop failures in the southwestern part of the province due to increased moisture stress on crops, with corn and soybeans becoming particularly risky should droughts become more frequent.[10] In addition, there is the possibility of significant crop damage stemming from higher ground-level ozone levels during summers.

- *Tourism and recreation*—declining lake levels and disappearing wetlands will eliminate the tourism and recreation associated with parks such as Point Pelle on Lake Erie, and the downhill ski season in the South Georgian Bay region could be eliminated along with $39 million in skier spending; summer recreational activities, however, would likely enjoy extended camping seasons at provincial parks.[11]

- *Urban air quality*—warmer summers will mean greater urban smog, since the formation of smog is dependent not only on the presence of certain air pollutants emitted by automobiles, power plants, and industries, but also temperature. Rising ozone levels will cause increasing pulmonary damage among people living in urban areas, and indirectly contribute towards the formation of acids in the air that further harm human health.

- *Forests*—For each 1°C of warming, tree ranges have the potential to expand 100 kilometres northward, and the potential northward shift of the boreal forest climate (southern boundary) could range from 250 to 900 kilometres. But the northward shift in climate would likely occur more rapidly than the species can migrate. Hence higher temperatures, lower soil moisture, and more frequent drought conditions will place greater stresses on forest resources leading to greater damages from pests, disease, and

wild fires and major dislocations of supply.[12] In 1989 alone, close to one percent of the province's total forest land burned from wild fires as a result of drought conditions, a possible harbinger of the future.[13] Since forest planning and policy development assumes a 50-100 year horizon, the minimum rotation ages of most eastern Canadian tree species, the potential rapidity of climate change compels, at the very least, a re-examination of present forest management policies.[14]

The most significant ecological impact of global warming on Ontario's natural resources may be the effect of rising temperatures on the Hudson Bay Lowlands that cover 32,000 square kilometres of northern Ontario, as well as Manitoba, and Quebec. As the second largest continuous wetland region of the world, after the Siberian peatland of the U.S.S.R. (see accompanying map), these wetlands are significant because they become net producers of methane and other greenhouse gases when they warm up, as they are composed of a significant fraction of water saturated organic matter.

Preliminary research from the Northern Wetlands Study, a joint investigation being undertaken by Canadian universities and NASA, indicates that these wetlands are quite sensitive to changes in temperature and could be expected to add significant loadings of greenhouse gases, especially methane, to atmosphere as the northern hemisphere warms up.[15] This is known as a "positive feedback", i.e., terrestrial effects of global warming that amplify the warming trend even further.

In sum, the implications of global warming for Ontario's economy and natural resources—especially forests, soils, and the Great Lakes watershed—may be potentially very significant, not only disrupting economic benefits obtained presently from these resources but increasing future loadings of greenhouse gases to the atmosphere resulting from positive feedbacks.

NATIONAL AND INTERNATIONAL LEADERSHIP. Can Ontario, acting alone among the provinces and territories, make a difference? While the province produces only about one percent of global CO_2 emissions, it produces roughly a third of Canada's emissions. At present, Canada and the U.S. are alone with Turkey among the nations belonging to the Organisation for Economic Co-operation and Development (O.E.C.D.) refusing to take significant steps to curb global warming. While two federal Environment Canada ministers have made a commitment to stabilize Canada's CO_2 emissions, the Green Plan's National Action Strategy for global warming would only stabilize *net* emissions, allowing tree planting to offset future rising CO_2 emissions.[16] So Canada's present policy occupies a retrograde position from previous commitments.

In the Coalition's view, a serious commitment by Ontario to reducing CO_2 emissions would be a positive challenge to the federal government and other provinces, and it would surely spur forward action on this issue. Indeed, the province and municipal governments actually have a great deal more jurisdiction and authority to carry out policies to reduce CO_2 than the federal government. The keys to such a strategy lie in provincial rulemaking under the Energy Efficiency Act, the provincial building code, and the Clean Air Program (CAP), as well as joint jurisdiction with municipalities over transportation and land use planning. The province also has the means to effect changes in the market for new technologies that can reduce CO_2, as well as the authority to introduce structural reforms of electricity and gas utilities that would encourage greater energy efficiency and use of renewable energy technologies.

OPPORTUNITIES FOR INDUSTRIAL RENEWAL. Finally, the recession, terrible as it is for Ontario, presents the new government with important opportunities for restructuring the economy to make it more competitive in international markets. The initiatives needed to implement a provincial global warming strategy—energy efficiency and renewable energy—can help

foster such a needed industrial renewal. Some industries heavily reliant on primary energy, such as iron and steel, will need to improve energy efficiency to reduce factor costs in order to remain competitive. Other sectors, such as agriculture, forestry, and light manufacturing will benefit significantly from a provincial commitment to develop renewable energy resources, such as the production of ethanol from starchy crops or woody biomass, high performance windows, solar hot water heaters, and a large variety products that enhance the thermal performance of buildings.

Recent studies of international competitiveness show that the nations with the most rigorous environmental standards often lead in the export of the affected products. Germany, for example, has long had perhaps the most stringent stationary air pollution requirements, and German companies now appear to hold a world wide lead in patenting and exporting air pollution control equipment.[17] With respect to global warming, Germany has now gone the furthest among industrial nations in its commitment to a 25 percent CO_2 reduction target by 2005. It comes as no surprise, then, that Germany has mounted an industrial initiative to ensure its world leadership in the manufacture of photovoltaic technologies, which will play a role in meeting the target. It assisted Siemens to acquire ARCO Solar in 1990, which has developed the leading contender for low-cost, thin film technologies ready to be commercialized in the 1990s.

There is no reason why Ontario cannot do the same. While at first exacting standards may raise costs and make firms less competitive, if properly formulated they will encourage innovation and the re-engineering of technology. The result eventually will be lower costs, and new products and processes that can be exported. Chapter 7 explores these themes in greater detail.

In sum, the Coalition believes a strong provincial policy on global warming makes sense. Such a policy would not only be in the province's long-term ecological and economic interests, but consistent with new policy initiatives such as the nuclear moratorium and new energy efficiency programmes. In addition, the province will be in a better position to influence the direction of the issue nationally (if not internationally) in the years ahead.

1.5 Framework and Methodology

This report explores the measures and policy strategies that would be required to achieve a 20 percent reduction in CO_2 emissions in Ontario by 2005. Since the Ministry of Energy projects that CO_2 emissions will rise about 21 percent by 2005, the 20 percent cut actually represents a 43 percent cut from emissions forecast for the year 2005.[18]

The report's analysis starts with the Ministry of Energy's estimates of primary and secondary energy use and CO_2 emissions for 1988 and 2005, as shown in tables included in Appendix A. Table 1 summarizes the Ministry's estimates for Ontario's CO_2 emissions in 1988 and 2005. Key assumptions of the Ministry's forecast include:

- average economic growth during the 1989-2005 period of three percent per year;
- average energy demand growth of 1.9 percent per year for all sectors, 2.6 percent in the industrial sector; and
- an implied built-in reduction in energy intensity averaging 1.1 percent per year.

In the Ministry's assumptions, electricity demand growth will be met by the Darlington nuclear station; 2,000 MW of non-utility parallel generation, of which 200 MW is hydraulic and 1,800 MW natural gas cogeneration; and a mix of new Ontario Hydro supply based on its proposed plan, which includes new nuclear power stations. The result is a decline by half in

the CO_2 electricity emissions rate by 2005 from its level in 1988, which explains the 25 percent reduction in CO_2 forecast emissions in this sector.

Table 1 (a): Ministry of Energy Summary of Ontario's CO_2 emissions, 1988 and 2005

Sector	1988 CO_2 (Mt)	% share	2005 CO_2 (Mt)	% share	% change 1988-2005
Residential	19.0	12%	19.4	10%	+2%
Commercial	10.8	7%	12.8	7%	+19%
Industrial	50.1	30%	74.8	38%	+49%
Transport	42.4	26%	54.9	28%	+30%
Non-energy	0.8	1%	1.7	1%	+113%
Own uses and losses	8.9	5%	10.7	5%	+20%
Electricity generation	32.3	20%	24.1	12%	-25%
TOTAL	164.3	100%	198.4	100%	+21%

See Appendix A for detailed breakdown.

Another way to view the province's CO_2 emissions is to proportionately factor emissions from own "uses and losses" and "electricity generation" into each of the end-use sectors. While this approach oversimplifies matters somewhat—different sectors demand electricity in different time patterns and fuel mixes, for instance—it does give a more realistic snapshot of the contribution the different secondary energy end-uses make to CO_2 emissions in a specific year. Viewed this way, energy consumption by Ontario's residential and commercial buildings is responsible for almost a third of the province's CO_2 emissions, industries somewhat more than a third, and transportation somewhat less than a third.

Table 1 (b): Consolidated Summary of Ontario's CO_2 emissions, 1988

Sector	1988 CO_2 (Mt)	% share	CO_2 Intensity (tonnes/MJ)
Residential	30.5	18%	37
Commercial	21.2	13%	33
Industrial	64.2	39%	49
Transportation	46.3	28%	69
Non-energy	2.6	2%	10
TOTAL	164.8	100%	44

In this report, three strategies are examined in each of the end-use sectors: energy efficiency, fuel switching, and renewable energy measures.

- ***Energy efficiency.*** Strategies include retrofit of buildings and industries with measures to improve thermal and electrical efficiency, as well as modifications in the provincial building code that require future buildings to be less energy intensive. In addition, various market-based incentives and educational initiatives are examined to encourage consumers to purchase more energy efficient vehicles and homes.

- ***Fuel switching.*** Since burning natural gas produces less CO_2 than burning other fossil fuels, various measures are examined to encourage wider use of natural gas especially for space and water heating and use as a motor fuel, substituting for oil and coal-fired electricity generation.

- ***Renewable energy.*** Strategies include wider use of passive and active solar heating in buildings, substitution of ethanol for gasoline in a blended motor fuel, and harvesting wood on a sustainable basis to ensure that it is a renewable energy source.

MEASURES ECONOMICALLY ATTRACTIVE TO SOCIETY. The Coalition identifies selective measures to reduce CO_2 emissions it deems "economically attractive to society" in each sector in Chapters 2-6, based on a survey of the pertinent literature and interviews with energy efficiency and renewable energy experts. The measures are not meant to be comprehensive. Indeed, a number of options with significant potential for abating CO_2 emissions, such as waste reduction and recycling, were not addressed due to limited time and funds.

The report does not give a rigorous quantitative definition for "economically attractive to society", nor does it estimate the capital costs of the measures, which would have been beyond the scope and funding provided for this project. Defining "economically attractive" isn't easy, especially when the many federal, provincial, and private studies reviewed differ so widely in their assumptions about future energy prices, discount levels, and other technical details. The choice of discount level, for instance, significantly affects the economics of an investment, with low rates favouring heavily capital intensive options, such as nuclear reactors. The selection of the rate in forecasts or commissioned studies may tend to reflect the priorities or interests of the agency sponsoring the forecast or study.

Differing perspectives on "payback" also confound the definition of what is "economic". Many industries won't accept more than a two year payback on energy efficiency measures in a local factory, because they may be able to invest their capital in another enterprise or country at a higher rate of return. On the other hand, a home owner, who cannot pass energy costs on to someone else, may be willing to accept a longer payback period. Indeed, a home owner may even be willing to make "irrational" investments that are not economic on paper, but that meet other needs.

Assessing the economic costs and benefits of measures is also tricky because true cost effectiveness would measure only the costs of interventions taken solely to reduce CO_2 emissions. In practice this is nearly impossible since many of the actions required to reduce CO_2 emissions will also contribute positively to the attainment of many other environmental or social goals, such as the abatement of urban smog (substitution of natural gas), alleviation of traffic congestion (modal shift to public transit), or the improvement of the health of the province's farm economy (shift to ethanol as a transportation fuel). Furthermore, even if a framework for the assessment of multiple benefits could be formulated, monetizing environmental risks and benefits remains a difficult business.

On the other hand, economic analysis can be a valuable tool in assessing the relative costs and benefits of different measures, enabling government to design a least-cost policy approach and to prioritize measures.

The analysis of the potential reduction in CO_2 emissions that implementation of such measures could bring starts with the base data given in Table 1(b), consolidating emissions from own uses and losses and electricity emissions in each of the four end-use sectors. Detailed analysis of measures applied in each sector is provided in Appendices B-E. The effect of the measures on electricity demand in each sector are noted and consolidated in Appendix F, which discusses the implications of those changes on the fuel mix and the CO_2 emissions rate from electricity in 2005.

CAVEATS. The analysis in this report covers about 75 percent of the Province's emissions inventory. The sectors that do not receive complete coverage are the commercial and

transportation sectors. In the commercial sector, the category of "other" commercial space, 31 percent of the sector in the Ministry of Energy's inventory, is omitted because of the lack of adequate information on it. In the transportation sector, the analysis focuses on energy use by passenger automobiles, close to 50 percent of the sector, because time and resources did not permit adequate investigation of the truck, marine, and air transportation modes.

In the industrial sector, our analysis assumes the previous 20-year energy demand growth rate, 2.1 percent, instead of the rate forecast by the Ministry of Energy in its projections, 2.6 percent. (During the course of this study the Ministry revised its reference case forecast downward.) The reasons for our assuming a different growth rate are explained in the next section.

Distinguishing an efficiency improvement factor—energy conservation that occurs "naturally" in response to prices and to available incentives—is more difficult to do in the industrial sector, where growth often results from increased utilization of existing capacity. In other sectors, the energy characteristics of new units of housing, office buildings, or passenger cars can be identified and enumerated more easily. Such an analysis in the industry sector was beyond the scope of this effort. Our simplified assumption that energy demand growth in the industrial sector will approximate the historic trend, therefore, assumes some imbedded energy conservation. As a result, care should be taken in reviewing the efficiency measures presented in the industrial sector, as there is no doubt some "double-counting" among the specific measures discussed, such as installation of energy efficient motors, and the conservation embedded in future growth.

With such caveats in mind, our analysis, through a survey of the literature, does attempt to evaluate those measures that pay back in a reasonable period of time from a societal point of view. The assumption is made, of course, that studies conducted in other jurisdictions are relevant to Ontario. Other long-term ancillary benefits, such as support for new industries, job growth in Ontario, or reductions in urban smog, are also weighed where appropriate.

1.6 Forecasting Provincial CO_2 Trends

If it weren't for population and economic growth, achieving the Toronto target by 2005 would not be difficult. The relative difficulty of achieving the target really stems from our estimation and perception of how much growth is forecast over the next 15 years.

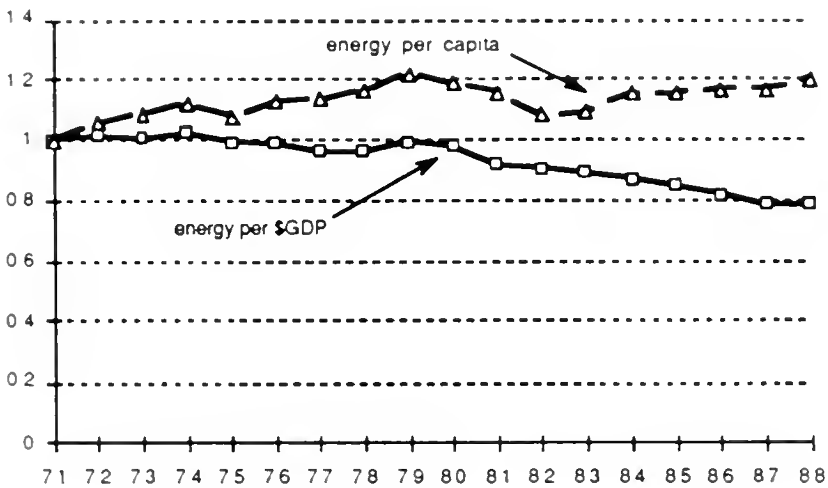
Trends in the province's emissions of greenhouse gases such as CO_2 are especially connected to (i) trends in economic growth and energy intensity, and (ii) weather, as expressed as annual degree days and as annual precipitation in key watersheds that supply the province with hydraulic energy. While it is beyond the scope of this report to explore these trends in detail, an overview is provided as an introduction to the sectoral chapters that follow and to emphasize the perils of determining a course of action on global warming based on forecasting.

The more the economy expands (or contracts), the more (or less) energy it requires. On the other hand, the relative extent to which economic growth and energy demand are linked is a function of energy intensity, or the amount of total primary energy requirement associated with a dollar of gross domestic product (GDP). (Energy intensity can also be expressed in different sectors of the economy as energy per capita, per square foot of floor space, per vehicle-kilometre, etc.) The underlying factors that affect changes in energy intensity include:

- structural changes in the economy, such as the shift away from energy intensive industries to less energy intensive products and services now occurring in all industrial economies;

- efficiency improvements in end-uses such as homes, offices, and industries resulting from: (i) technological advances that reduce energy use without changing basic products or services; (ii) market changes, such as higher energy prices, that affect consumer behavior, and (iii) government policies to encourage greater efficiency.

Figure 1: Trends in Ontario's Energy Intensity, 1971-88



During the 1980s, a fundamental shift in Ontario's energy intensity occurred that resulted in stabilization of provincial CO_2 emissions during a period of robust economic growth, with the provincial gross domestic product growing from 161 billion in 1979 to 229 billion in 1989, an average annual rate of 3.6 percent (in constant dollars), despite the 1980-81 recession. Energy intensity declined at an average annual rate of 2.3 percent. Primary energy demand slowed to an average annual increase of 1.6 percent. (See Figure 1.) The underlying reasons for these changes include:

- the OPEC price shocks and federal government's reaction to them with initiatives such as the Canadian Home Insulation Program (C.H.I.P.);
- the influence of American efficiency regulations, such as the Corporate Average Fuel Economy (C.A.F.E.) standards for automobiles, which led to Canadian adoption of comparable voluntary guidelines;
- significant technological advances in the efficiency of products and equipment;
- structural changes in the provincial economy towards rapid growth of light manufacturing and services, leading to a declining energy share of heavy industries.

Although the Ministry's forecast assumptions include "significant energy efficiency improvements arising from market forces and regulations", its estimates of energy demand and intensity trends for the next 15 years differ markedly from the experience of the last 10 years. They are bearish on change in energy intensity and bullish on change in energy demand. Energy intensity is expected to slow to half the rate of the 1980s, while energy demand is forecast to increase at a faster rate. One reason is positive expectation about the potential impacts of free trade. After a period of painful adjustment, free trade is expected to lead to robust growth among Ontario's resource based industries, such as iron and steel. As a result, a 50 percent rise in CO_2 emissions is forecast for the industrial sector, with annual energy demand growing 2.6 percent on average, almost twice the average annual growth of 1.9 percent experienced during

the 1980s. Another reason is the Ministry forecasts that "real" energy prices (in constant dollars) will not rise as much as they did in the early 1980s.

The Ministry's forecasts were made before the onset of the present recession and just as the Free Trade Agreement was going into force. In addition, the unification of Germany and liberalization of Eastern Europe had just begun to unfold, and the Kuwait war was far in the distance.

There is room for argument that the eventual impact of these events, not to mention the uncertain outcome of Canada's constitutional crisis, will compel the provincial economy down a road towards 2005 that looks very different from the one presently envisaged by forecasts.

Here is an alternative view posed by some economists. The triple whammy of the recession, the FTA , and the federal government's high interest rate policy are now leading, many economists believe, to a permanent loss of part of Ontario's industrial base and jobs. As the rebuilding of eastern Europe and Kuwait soak up massive amounts of Japanese and German capital during the 1990s, interest rates, after a temporary dip during the recession, return to higher levels, acting to further limit the supply of new capital Ontario's industries desperately need to modernize and to become more competitive. Ontario's energy intensive industries that survive and grow will do so by reducing factor costs associated with energy use, by capitalizing on new technologies, and by innovating. Structural shifts already underway in the economy will continue if not accelerate in the 1990s. As a result, in 2005, Ontario's economy would likely be much more service and light manufacturing oriented than it is today, with its competitive edge supported more by education and technological leadership, and less by natural resources. In such a scenario, the decline in provincial energy intensity seen during the 1980s would also likely accelerate, the effect being to moderate future emissions of CO_2 even as the economy returns to vigorous growth.

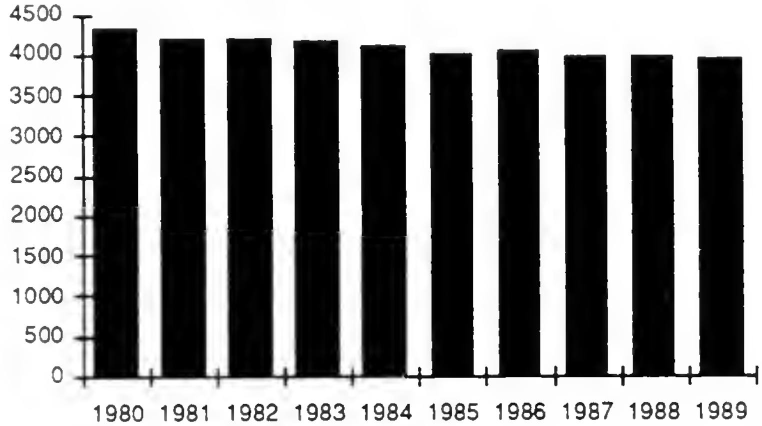
The Coalition isn't advocating such a scenario. Indeed, if such a scenario were to take place—in particular if interest rates were to return to higher levels after the recession and stay there throughout the 1990s—the investment needed to modernize the economy and to achieve greater energy efficiency in sectors such as housing would be more difficult to come by. The scenario is presented merely to emphasize the perils of forecasting and the difficulty of reaching a consensus about what the future may hold.

Future CO_2 emissions will also be affected by trends in weather that may be linked to global warming. Space heating of buildings is an important source of provincial CO_2 emissions, and space heating requirements are influenced by the number of annual degree days. As already noted, average winter temperatures have risen in Ontario over the past 30 years. The long-term trend in degree days, therefore, appears downward, decreasing over the past decade at one percent on average each year (on the basis of a five year rolling average) in Consumers Gas's central region.[19] If this downward trend continues over the next two decades, it could moderate future CO_2 emissions by reducing demand for winter heating fuels and electricity. Presently, the Ministry's forecasts do not take into account the weather factor, even though winter heating accounts for an important share of the province's energy use and CO_2 emissions.

Precipitation trends may have the opposite effect on CO_2 emissions, to the extent that periodic droughts reduce runoff into watersheds upon which the province's hydraulic generation depends. A dry period during 1988, for instance, lowered water levels in the Great Lakes, thereby reducing hydro capacity at Niagara Falls. The reduced capacity compelled Ontario Hydro to increase electricity generation at coal-fired power stations to make up the difference, leading to an increase in the province's CO_2 emissions. As mentioned earlier, regional climate

effects studies suggest that Ontario may experience more frequent droughts that would periodically affect the province's watersheds and hydro capacity.

Figure 1 (b): Winter Degree Days, Central Region, 1980-89 (5 year rolling average)



Source: Consumers Gas

The foregoing discussion of economic and weather factors that may influence future CO_2 emissions underlines some of the uncertainties of forecasting these emissions 15 years in the future. Political events, not to mention ecological surprises, have a way of overtaking economic trends in unexpected ways, and the events of the past year amount to no less than a global upheaval. As Ontario's economy strives for international competitiveness and markets in a rapidly changing global economy, who can really predict what kind of industrial capacity will eventually thrive? And more political change is yet to come, as Quebec and other provinces face a showdown over the future of Canada. How will Ontario's population growth and economic prospects be affected?

No one really knows.

The government should continue to revise and refine its forecasts as a useful guide; the Ministry of Energy, for instance, should consider collaborating with the Ministry of Environment and Environment Canada to identify the potential impacts of global warming on the province's space heating (and cooling) demand and existing and planned hydro capacity. In the view of the Coalition, however, forecasts of energy demand and CO_2 emissions much beyond five years should be treated with healthy skepticism. Whatever the long-term forecasts may be, policymakers should concentrate on how to achieve maximum reductions in energy intensity that are economically feasible and to decouple energy demand from economic growth. In other words, achieving reductions in energy intensity in the various sectors should be a provincial goal, as important as achieving greater energy efficiency in the operation of equipment, appliances, vehicles, and processes. Promoting lower energy intensity means encouraging the growth of less energy intensive industry, land use, and life styles; it implies promoting changes in the way we produce economic activity and the way we live. A parallel priority is identifying strategies to further decouple energy demand from CO_2 emissions, by encouraging the substitution of renewable energy for fossil energy sources.

Measures and policies to achieve reductions of CO_2 in the four end-use sectors of the economy—residential, commercial, transportation, and industry—are discussed in Chapters 2-

to-6. Corresponding Appendices D-E provide detailed information on the assumptions and calculations for each of the sectors, and Appendix F provides details on the calculation of a CO_2 emission rate for electricity consumption that is applied in each of the foregoing sectors. A case study of natural gas cogeneration technologies and steps the province could take to maximize benefits to the economy by helping to commercialize these technologies is included in Chapter 7. Chapter 8 outlines utility reforms to encourage high market penetration of energy efficiency and renewable technologies in the various sectors. Summary and conclusions are provided in Chapter 9.

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CHAPTER 2—RESIDENTIAL SECTOR

"One can only hope that a more generous attitude will prevail, an attitude that recognizes that a new and different generation of prospective homeowners, faced with higher interest rates, energy costs, and land prices, is obliged to consider housing solutions different from those that were available to their parents. This is no cause for alarm. It may be an opportunity to attain better—and more livable—towns and cities."

Witold Rybczynski, McGill University, a recent article for *The Atlantic*

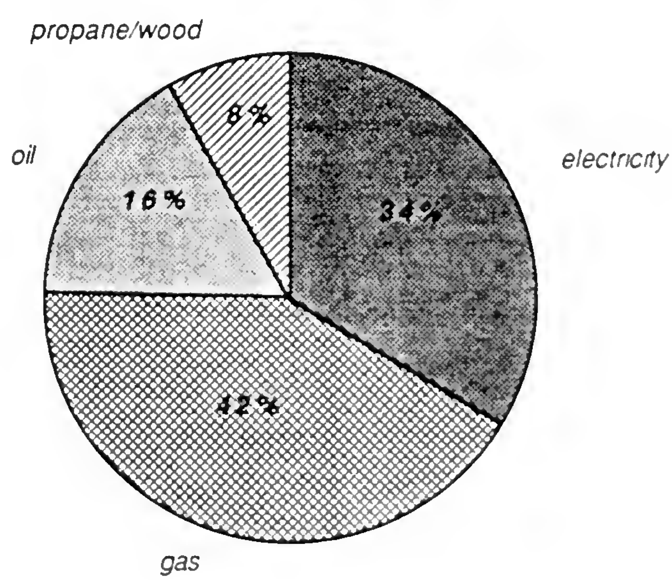
2.0 Introduction

There are close to 3.6 million homes in Ontario today. They include single family detached homes—58 percent of the housing stock—and single family semi-detached and row houses, as well as apartments. Together with the people who live in them, the province's homes and apartments consumed 823 petajoules (PJ) of energy in 1988, about 22 percent of the province's total energy or about 140 GJ of secondary energy per household. About 1.1 million new homes and apartment units are forecast to be built over the next 14 years, an increase of 31 percent (not including demolitions), about half in the Greater Toronto Area (GTA).

2.1 Profile of CO_2 emissions

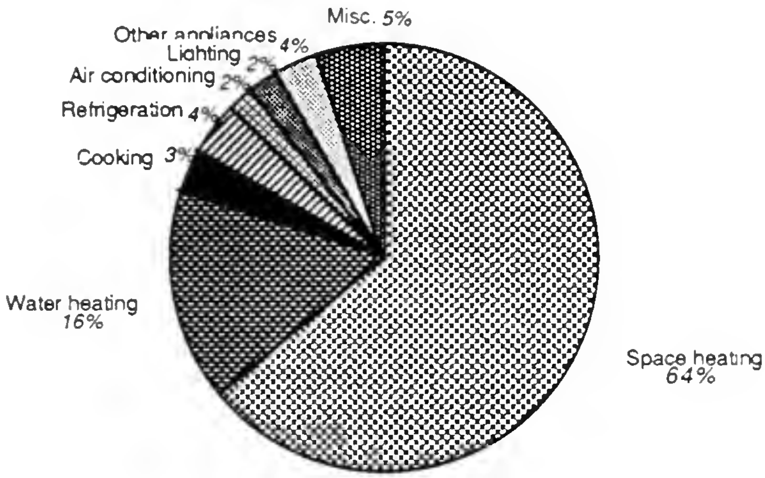
In 1988 energy use in Ontario's residential sector produced 30.5 megatonnes (Mt) of CO_2 emissions, about 18 percent of the province's total. The largest share of emissions stems from the burning of natural gas, followed closely by electricity generation. Virtually all electricity related CO_2 emissions come from coal, which accounts for about 25-30 percent of Ontario Hydro's generation mix today.

Residential CO2 Emissions by Source,1988



Ontario homes produce an average of seven tonnes of CO_2 each year. Space heating produces almost two-thirds of a typical home's CO_2 emissions, with the balance associated with water heating (16 percent) and appliances (13 percent). Row houses and apartments, because they are smaller in size and less energy intensive (units of energy consumed per unit of floor space), may produce half the CO_2 emissions as detached homes.

CO2 Emissions by Residential End Use, 1988



The Ministry of Energy's forecast projects that by 2005, emissions of CO_2 from the residential sector may increase only about two percent (see Appendix A). This is largely because the Ministry forecasts that coal will decline to about 12 percent of the generation mix in 2005, thus cutting the CO_2 emission rate of electricity by half and more than offsetting the modest increase in electricity's market share that is also foreseen. In addition, the Ministry forecasts that end use efficiency improvements in space heating will lead to a decline of heating energy per dwelling of about one percent per year, contributing to a modest decline in energy intensity in the sector over the next 15 years.

2.2 Profile of Energy Intensity Trends

There are several ways to describe energy intensity in the residential sector. The most useful measure is energy per unit of floor space, but figures are sketchy, making it difficult to analyse trends. A comparative snapshot is given in accompanying Table 2 (a). Row houses typically use less than three quarters—and apartments less than two-thirds—the energy that single and semi-detached houses use per unit.

Another useful measure of energy intensity is total residential energy per capita. Over the past 15 years there has been relatively little change in residential energy per capita, primarily because the number of persons in the average household has been declining due to lower birth rates and higher divorce rates. Whether there are five people living in it or three, it takes the same energy to heat a house. In addition, suburban expansion during these years pushed up the

average floor space of new houses from 1,500 sq. ft. in the 1960's to over 2,000 sq. ft. in the 1980s.

Table 2 (a): Energy Intensity of Ontario's Residential Housing

Dwelling type	No. of units	% floor-space	Average floor space m^2	Average energy inten-sity GJ/m^2	Average energy inten-sity GJ/unit
Single/ semi-detached[1]	2,356,507	76%	132	1.28	169
Row house[1]	193,782	5%	96	1.28	123
Apartments[2]	982,984	19%	79	.66	52

m=metre; GJ=billion joules
Note: Energy intensity for single, semi-detached, and row houses are derived from averages for single family housing. Because row houses have a higher volume to exterior wall ratio and a lower window fraction, they are more thermally efficient than single or semi-detached housing. In actuality, therefore, they have lower energy intensities than indicated here.

[1]Ministry of Energy and Canada Mortgage and Housing Corporation, 1988 estimate
[2]Ontario Hydro, 1990 Commercial End-use Forecast (December 1990), 1989 estimate

Finally, energy intensity can be measured as average energy consumed per household. Although the number of Ontario homes increased 50 percent over the period 1973-1988, the energy consumed by these homes increased only about 17 percent. As a result, energy use per household declined about 27 percent over the period.

The decline in household energy intensity was caused by several factors, among them:

- social trends mentioned above led to greater demand for smaller housing units like apartments, as well as less demand for hot water per household;
- federal government initiatives like the Canada Oil Substitution Program (COSP) and the Canadian Home Insulation Program (CHIP) encouraged 300,000 homeowners in the early 1980s to convert from oil to higher efficiency natural gas furnaces and to improve the thermal performance of their homes.

When compared with housing in many European nations and many U.S. states, the thermal performance of Ontario's housing appears relatively poor. Although cold climate is often cited as a reason for the relatively high energy use of the province's homes, when compared with housing in countries that experience comparable degree days of winter heating, like Sweden, Ontario's homes still appear wasteful. Single-family electric Swedish homes, for example, use an average of about 110 kWh/m^2 for heating annually, while Ontario homes use about 130 kWh/m^2.[20] The primary reason is that Sweden mandates more insulation in new housing than does Ontario.[21]

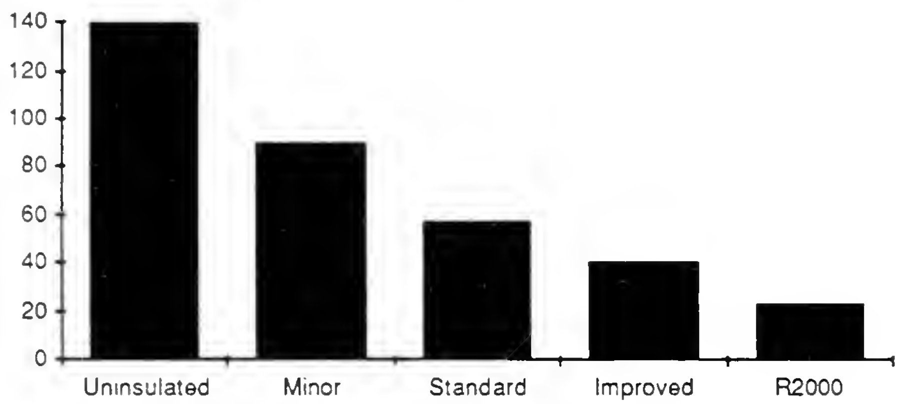
2.3 Opportunities for CO_2 Reductions

Significant energy efficiency potential remains in Ontario's housing stock. In addition, the efficiency of the best gas furnaces is now approaching 95 percent and should make attractive the substitution of natural gas for electric heating. Finally, untapped potential for renewable energy exists in active and passive solar water and space heating, advanced windows, and air sealing.

Efficiency Potential

According to the Canada Mortgage and Housing Corporation (CMHC), about one-third of the province's single-family dwellings have no or only minor insulation. Typically these homes were built prior to 1945 before building codes required any energy efficient construction. Sometimes they have small amounts of cellulose insulation in the ceiling. These homes typically consume two-to-three times more energy for heating than homes built today. (See accompanying figure.) Retrofitting these homes with a combination of air sealing, insulation, and high efficiency furnaces to achieve thermal equivalence with new homes being built today would save about 62 PJ annually, about 13 percent of the province's total secondary residential energy and would be cost effective according to a recent study.[22]

Figure 2(c): Average Annual Heat Load of Residential Archetypes



Source: Canada Mortgage and Housing Corporation and Hot 2000 analysis

An energy efficiency retrofit carried out on an older home in Toronto in 1982, however, demonstrates that the technical energy efficiency retrofit potential in older housing is much greater.

The Howland House, a single family, detached house, was remodelled in 1982 by the Ministry of Municipal Affairs and Housing to show what a maximum thermal retrofit, undertaken in connection with typical renovation work, could accomplish. The higher insulation levels, combined with a more efficient furnace, heat recovery ventilation, and passive solar heating on the third floor, achieved a reduction in energy used for annual space heating from 293 GJ to 17 GJ, a reduction of 94 percent. Although the project was designed as a technical demonstration project, most of the measures could be implemented in existing homes when major renovation is undertaken, at an incremental cost that is economically attractive.[23]

Recent EMR studies of residential efficiency retrofit potential using extremely conservative assumptions (no energy price rise in the next 30 years) indicate that a variety of cost effective strategies exist. For instance, one study examined a variety of options for improving the thermal efficiency of the different archetypes of homes. The measures included: air sealing; retrofitting high performance windows; and installation of high efficiency furnaces and heat recovery ventilators to ensure adequate ventilation. Savings would be 62 PJ or 20 percent of the province's residential energy consumed for heat, at a cost of less than 4¢/kWh.[24]

Studies of electrical efficiency potential only in Ontario commissioned by the Ministry of Energy and undertaken by Ontario Hydro indicate a range of 29-to-43 PJ of economic savings is possible in the residential sector by 2000 on a life-cycle cost basis of $.07/kWh or less, with most measures costing less than $.05/kWh. Such efficiency potential represents a savings range of 18-to-27 percent of projected electricity residential use in 2000 as projected in these studies.[25]

As for new housing, the Advanced House illustrates what is possible with commercial technology today, if singular attention is paid to construction technique and materials. A typical suburban home built in Brampton in 1989, the Advanced House was designed to exceed the energy performance of R2000. Incorporating passive solar design, high performance windows, compact fluorescent lighting, and high efficiency appliances, the house uses annually a total of 40 GJ, compared with 100 GJ for a R2000 house of similar size and 125 GJ for a house of similar size constructed to present provincial building code standards, a reduction of 70 percent from present code. The only advanced feature of the house is an integrated mechanical system that combines the functions of heating, cooling, heat recovery, and ventilation in the same equipment. Simple payback from energy savings accrued by the Advanced House, compared with present building code, is about 10-15 years. The 20 kW of peak power saved by the house cost $1,000/kW, less than a new power plant.[26]

Fuel Switching Potential

About 12 percent of the residential sector's space heating loads are presently met by electricity, and the Ministry of Energy forecasts this share will rise by 18 percent to 61 PJ by 2005. Since electricity space heating loads constitute the primary component of the province's winter peaking demand, which is met by anywhere between half and three quarters coal-fired generation, CO_2 reductions can be achieved by substituting natural gas furnaces for electric heating when major renovations are done, and by restricting the future use of electric resistance heating in new construction.

There are two reasons for a fuel switching strategy in the residential sector. First, significant thermal and distribution losses occur as fossil or nuclear power is generated in a steam boiler and then transmitted over the grid. Typically less than a third of the energy released by coal when it is burned, for instance, reaches the home, making electric water and space heating in the home only about 25-30 percent efficient overall. On the other hand, high efficiency natural gas furnaces rated 85-95 percent are now commonplace. Substituting natural gas space and water heating for existing electric heating would lower CO_2 emissions, as well as reduce the demand for electricity and the need for new power plants. Second, natural gas produces about half as much CO_2 as coal per unit of energy when it burns.

The aforementioned EMR studies indicate that retrofit of high-efficiency furnaces in 80 percent of Ontario's single family homes could be done for 6¢/kWh or less. While the economics of such retrofits will be affected by how much air sealing, insulation, and higher performance windows measures are done first—such measures will tend to reduce the cost effectiveness of furnace replacements—many homes heated with electric furnaces that already have ventilation ducts will present good economic opportunities for fuel switching.

Economic applications of fuel switching also exist in high-rise apartment complexes, where hot water typically circulates continuously to each unit so the occupant doesn't have to wait when the faucet is opened. Present technology permits use of this existing hot water distribution system in the building for space heating purposes.

Some areas of the province, especially northern Ontario, do not have access to natural gas. These areas tend to be served by oil, electric, or wood heating. High efficiency furnace

options for these fuel sources, however, are also commercially available. One promising electric option, for instance, is the ground source heat pump, with efficiencies in the 200-240 percent range that almost entirely make up for the low system efficiency that characterizes electricity generation and distribution. Potentially these could replace electric furnaces and hot water heaters. In addition, new technologies such as the all-electric integrated mechanical system demonstrated in the Advanced House should become commercially available in a few years. Such advanced electric technologies can easily be combined with passive solar design to reduce the capacity of the heating systems installed.

Renewable Energy Potential

Renewable energy represents the most important untapped resource in Ontario's residential sector. A recent study of the passive solar potential in Canada concluded that significant opportunities exist for commercialization of new technologies such as high performance windows, integrated mechanical systems such as the one installed in the Advanced House, and thermal storage. In Ontario's residential sector, the study estimates the reasonable market potential to be 61 PJ by 2010.[27]

The solar water industry in Canada has estimated that about 75 percent of Ontario's homes could be retrofitted with solar hot water heating, offering a displacement of about 26 PJ of conventional fuel, or a total of 50 PJ when "own uses and losses" and the low system efficiencies of electric water heating are taken into account. The technology is commercial today, and Ontario companies that produce domestic solar hot water systems, such as Solcan Industries, have long been marketing well proven systems.[28]

One niche application of solar water heating that offers considerable promise is the heating of swimming pools. Of the 280,000 outdoor pools in Ontario, about 75,000 are heated, largely with gas. In addition, approximately 15,000 new in-ground pools are built each year, about half heated with natural gas. With appropriate incentives, it is estimated that 80 percent of these pools would switch to solar hot water heating. Combined with an initiative to replace the motors that are used in the circulating pumps of these pools with more efficient motors, a total of 5.4 PJ could be saved.[29]

A recent report commissioned by EMR suggests that photovoltaic power could be competitive with grid electricity by 2010. U.S. studies suggest that the timeline for commercialization of PVs for conventional applications—as opposed to to use in remote locations and for small niche markets—is much nearer, 1995-2000 for, some advanced film technologies. Advances will bring the cost of PV power down significantly by the mid-1990s. The most promising thin film technology appears to be copper indium diselinide (CIS). Siemens Solar Technologies, which last year acquired ARCO's CIS and silicon PV business and research labs for $30 million, may be the first to offer 10 percent efficient, stable, low cost modules in 1993-95. CIS modules costing $50/m^2 appear to be feasible in the near-term, which would mean that in New York, the total cost for intermittent peaking power provided by CIS PVs may be below 6¢/kWh by 1995![30]

Given the rapid advances being made in PV technologies—several Ontario firms are leading Canada's effort to develop thin film technologies—it is difficult to estimate the potential in Ontario. Accepting the estimate from the EMR commissioned report, there may be a potential of only 1 PJ in Ontario over the next 10-15 years. If the more optimistic projections being reported by the Solar Energy Research Institute hold true, however, the potential could be significantly higher, particularly for the residential and commercial sectors, where PVs sited on roof tops to provide intermittent peaking power would require no energy storage.

In sum, a potential of 110-120 PJ of renewable energy exists in the residential sector in the existing building stock.

2.4 Measures to Reduce CO_2 Emissions

Measures applied to single family residential buildings are described in detail in Appendix B, while multi-family residential buildings are described in Appendix C. The economically attractive measures assumed to reduce CO_2 emissions in single-family residences include the following:

RETROFIT TARGETS (2005) FOR SINGLE-FAMILY RESIDENCES:
Efficiency scenario:
•Improvements in thermal envelope and furnaces reduce heating energy in 70 percent of the building stock by....................25%
•Reduction in cooling energy in all buildings by 25%
•Significant penetration of compact fluorescents reduces lighting energy by 60%
•Improvement in average efficiency of water heater stock of....................25%
•Improvement in average efficiency of refrigerator stock of....................40%
•Improvement in average efficiency of clothes dryer stock of....................25%
•Improvement in average efficiency of cooking appliance stock of....................20%
•Electric heat pumps average 200 percent efficiency in the following percentage of homes that presently have heat pumps....................75%
Fuel switching scenario:
•Switch from oil to gas space and water heating by....................50%
•Switch from electricity to gas space and water heating by....................20%
Renewable scenario:
•Retrofit domestic solar water heating in 30 percent of building stock, saves.......... 22 PJ
•Retrofit passive solar heating technologies, such as attic heat return, in 10 percent of building stock, saves....................16 PJ

ENERGY INTENSITY TARGET FOR NEW RESIDENTIAL:
It is assumed that the average energy intensity of new residences, as a result of biennial modification of the provincial building code, declines gradually to 40 GJ for a typical 2,000 sq. ft. home (equivalent to the energy rating of the Advanced House) from the present code standard of about 125 GJ for an equivalent sized house. These figures include total energy use, i.e., heating, cooling, appliances, etc. The same proportional decline is applied to row houses. The decline occurs in the following steps (per unit of housing):

	1989-90	1991-92	1993-95	1996-99	2000+
Detached + semi	150 GJ	125	100[1]	60	40[2]
Row	110 GJ	90	70	45	30

[1]R2000; [2]Advanced House

The average energy intensity of new multi-family residences declines 50 percent from the average level of the 1988 multi-family building stock by 2005. Hence, apartment stock constructed 1988-2005 would average .4 GJ/m^2 or 8 kWh/ft^2 in 2005. Details are provided on new multi-family residential buildings in Appendix C, Tables C-6 and C-11. One caveat is in order. These projections do not assume increasing use of electric appliances in the future, a continuing trend that will tend to increase home energy use in the future. On the other hand, the calculations are conservatively based on a 2,000 square foot house, somewhat larger than what is likely to be the average size of new homes over the next 15 years.

As a result of these measures, CO_2 emissions from the residential sector are reduced by 34 percent, assuming that electrical demand is met in 2005 by power generation that has a fuel mix described in Appendix F. The results are summarized in Appendix B, Table B-1.

It is clear that new housing offers the single most important opportunity for energy efficiency improvements. Over a million new homes and apartments may be built in Ontario in the next 15 years. Failure to require standards of construction that result in cost-effective en-

ergy savings represents an opportunity lost forever. For instance, while it costs about $5,000 more to build an R2000 house from start than to build one to the 1978 code, upgrading an existing 1978 house to R2000 may cost $10,000-20,000. At present energy prices, a new R2000 home pays back in energy savings in just 4-to-5 years, within the period of typical home ownership. In the equivalent retrofit case, the payback period is more likely to be 10-20 years and will be viewed as uneconomic by many home owners (although from the point of view of Ontario Hydro, investing in the retrofit in electrically heated homes could be a cost effective way to avoid the cost of new generation).

If biennial review leads to progressive upgrading of the energy standards of the Ontario Building Code codifying features of the R2000 protocol and the Advanced House, the average house built in the 1990s will use half as much energy as the typical house built in the mid-1980s. Further, if the province, in cooperation with utilities, seeks to develop and commercialize a host of advanced efficiency renewable technologies, such as super performance windows (R-10), thermal storage, and photovoltaics, *new housing could be on a trajectory towards no energy load growth by 2005.*

Upgrading the energy standards in the code will stretch the skills and technical capabilities of the building industry, and considerable effort will need to be put into training that disseminates air sealing techniques and analysis and other renewable technologies. In addition, initiatives to educate home buyers regarding the economic and environmental consequences of home energy use will need to be undertaken to change their buying preferences.

2.5 Barriers to Achieving Measures

The relatively high energy intensity of Ontario's residential sector is not due so much to climate, but to other factors:

- relatively low energy prices tend to discourage efficiency by making the payback for many measures longer than the period of home ownership, although many homeowners would no doubt pay more than is economically justifiable in order to "save the environment", were adequate retrofit programmes available to them;
- the problem of "split incentives", i.e., building owners pass energy costs on to renters;
- lack of information about home energy efficiency among architects, builders, engineers, and home owners;
- the domination of tract builders in the industry, whose construction practices often lack the flexibility or skills to incorporate solar or energy efficiency measures;
- speculative construction practices that put a premium on minimizing first costs;
- municipal land use policies, especially in the GTA, that favour sprawl, rather than compactness of new communities and row housing;
- weak energy standards in the provincial building code, reflecting a regulatory system that historically has catered mostly to the needs and perceptions of builders;
- lack of commitment by utilities to energy efficiency, or legal/regulatory barriers, such as a prohibition on Ontario Hydro that limits its energy efficiency programmes exclusively to electrically heated homes.

The most effective way to overcome these barriers is for government and the utilities to work together to provide high financial incentives—50-100 percent of the installation costs—to homeowners to undertake the major retrofit measures necessary.

Direct installation programmes work in the U.S. The federal Low Income Weatherization Program was set up 15 years ago by Congress to shield low income homeowners from the oil price shocks caused by OPEC. Each state set up its own programme and, with federal funds, has carried out an enormous variety of home retrofit programmes. The

most successful programmes in states like Wisconsin and Minnesota with cold climates are achieving 15-20 percent reductions in energy use for heating.[31] Such reductions are being achieved using simple weather stripping, caulking, window repair, and blown in insulation, with a cap of $1,600 cost per home. If the cap were higher, say double or triple, additional insulation, air sealing, ventilation measures, and furnace upgrading could achieve 20-40 percent reductions in heating energy use on homes situated in a climate similar to that of Ontario.

The keys to success of these programmes include:

- decentralization of decision-making with weatherization crews assuming full responsibility to ensure subsidies are based on results, not expenditures;
- involvement of the home's occupant in all facets of the project, guided by an "education protocol";
- careful attention to the cost effectiveness and health safety of retrofits;
- installation fully paid, up to $1,600 per house;
- use of the blower door, infrared cameras, and other sophisticated equipment for pre- and post-weatherization tests.[32]

The lessons learned from evaluation of these programmes and many other utility residential programs indicates that high market penetration and significant energy savings depend especially on direct personal contact with the home owner, high financial incentives, well trained and responsible retrofit crews, and a strategy that emphasizes cost effectiveness. In cold climates, such a strategy would always start with a significant effort to weatherize and seal a home. High efficiency furnace retrofits make more long-term economic sense afterwards, because the equipment can then be downsized.

2.6 What Ontario Can Do

Fortunately, the Province has a variety of regulatory instruments that it can use to encourage more efficient residential buildings, equipment, and appliances, especially the provincial building code and the Energy Efficiency Act. There is also need, however, for an energy transfer tax to address the equity issues raised as the costs of new housing rise reflecting incorporation of new efficiency measures. A major public education initiative is also needed.

Efficiency Strategies

A variety of strategies are recommended to address the aforementioned barriers. They include:

- biennial modification of the provincial building code to progressively reduce the energy intensity of new housing over the next 15 years;
- wider application of the Energy Efficiency Act to improve the efficiency of windows, furnace fans, fireplaces, and lighting;
- development of a home energy rating system to educate home buyers and owners, along with mortgages that reduce qualification criteria and rates for purchasers of energy efficient homes;
- establishment of an "affordable Homes programme" that encourages new row housing, as part of an overall urban intensification strategy for the GTA and other urban centres.

STRENGTHEN THE PROVINCIAL BUILDING CODE. For new housing, a high priority should be assigned to biennial revisions of the provincial building code to include incremental energy efficiency standards, initially on a prescriptive basis, but by the mid-1990s working towards a performance standard once the building industry acquires sufficient technical skill. A

go round in 1992 should capture the remaining measures necessary to bring all new housing up to, if not a little beyond the R2000 standard. These include: full height basement insulation: the R2000 air seal standard; requirement of adequate ventilation for health reasons; and double glazed, low-E, gas filled windows (R-3.6). The only barrier to the implementation of these measures is the skill of the builders in implementing the air sealing measure and testing for air tightness, but since many Ontario builders have gained considerable experience in this area (and Ontario Hydro already has a training programme), extension of this knowledge to the industry as a whole should not be difficult.

Presently, the building code does not apply to renovations of existing housing. It should. Up to half of the construction activity in this sector is typically renovation, representing significant opportunity for retrofit of walls and ceilings with insulation, replacement of windows with more energy efficient types, and construction of home additions to new building code standard. Revision of the building code in 1992, therefore, should apply energy codes for new buildings to renovation activity.

In 1994 and 1996, further incremental building code revisions should begin to incorporate standards that reflect the technologies and construction practices utilized in the Advanced House. These include:

- higher levels of insulation, including R-40 walls and R-60 ceilings by 1996;
- incremental improvements in energy efficient windows, with the aim of achieving R-4-to-R-6 performance in windows by 1996 (they are commercial now), and R-5-to-R-8 by 2000 (early commercial products now available);
- builder's option to choose an overall performance standard, as opposed to prescriptive standards for individual building components, that encourages the use of passive and active solar design by 1994.

To further encourage much wider use of solar heating in niche applications, such as swimming pools, consideration should be given to special taxes or hook-up fees, such as a tax or hook-up on pool heaters, to close the cost gap between the solar product and its fossil based alternative.

Further to these improvements for single family housing, a high priority should be placed on incorporating energy efficiency standards for apartments in the building code, perhaps based on current American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standards already in wide use in the U.S.

The key to the success of residential retrofit programmes implies the significant assumption by municipal electric utilities and municipalities—they have the most potential direct contact with residential energy users—for the implementation of such programmes and their willingness to offer high financial incentives that go beyond the rebate and loan programs now favoured.

Therefore, major reform of Ontario's utility regulatory framework would be needed requiring Ontario's private gas and public electric utilities to adopt "least cost planning" mandates that would put energy efficiency retrofit programmes on an even economic playing field with supply. Such reforms are discussed in Chapter 8.

Suggested retrofit priorities to start would be, in order of importance:

(i) low income housing, because people living near or below the poverty level will be hardest hit by the Ontario Hydro's 40-50 percent rate rise anticipated in the next few years;

(ii) electrically heated homes in northern Ontario, because rates are higher to start with and economic measures such as ground source heat pumps are available;
(iii) all remaining electrically heated homes in the province, because most homeowners will be particularly receptive to energy saving programmes;
(iv) the province's approximately one million uninsulated homes, because significant economic energy savings are possible;
(v) conversion of electric to high efficiency natural gas furnaces in area where ground source heat pumps are impractical and natural gas is available.

RAISE PROFILE OF THE ENERGY EFFICIENCY ACT. In addition to the foregoing improvements, a variety of "housekeeping" products should be immediately regulated under the Act. Fireplaces, furnace blower fans, windows, and lighting should be regulated under the Energy Efficiency Act. Furnace blower, ventilation, and exhaust fans and burner nozzles for natural gas and oil furnaces particularly offer important opportunities for energy efficiency gains. Fans, for instance, in many forced air systems use as much energy as the furnace itself, but their high energy use has generally escaped notice. Since 85 percent of Ontario's housing stock has forced air systems, they could offer a significant opportunity for energy reductions. To supplement the appliance rulemaking already in progress, immediate priority should be given to adoption of California's 1993 standards for refrigerators and other common household appliances, the most stringent in North America.

The Energy Efficiency Act could be one of the province's most important instruments for achieving reductions in energy use in all sectors, but the Ministry's staff assigned to the Act number only two persons presently. The staff should be considerably expanded and the profile of the office significantly raised. Commensurate with these steps, an on-going public consultation process should be undertaken to allow the staff to benefit on a regular basis from the wide experience on these matters that exists in the private sector and among environmental groups. In addition, funding should be available to permit representatives of environmental, consumer, and social housing groups to sit on the relevant Canadian Standards Association committees.

DEVELOP A PROVINCIAL HOME ENERGY RATING SYSTEM. Also important in educating consumers and realtors will be a uniform provincial home energy rating system, using as models perhaps the schemes that are gaining wide acceptance in the U.S. and the U.K. The rating would be applied to the sale of new and used homes, requiring an energy audit as a condition of sale. The home energy rating programme, however, should encourage home owners to rate their houses anytime during ownership, for instance, after a major renovation that incorporates efficiency measures, so that a shortage of auditors during high seasonal demand for housing sales, say in February and March, doesn't unduly hold up closings. (This has occurred in some state programmes in the U.S.)[33]

PROMOTE URBAN GROWTH BOUNDARIES AND AFFORDABLE ROW HOUSING. Finally, the province should undertake changes in the land use planning process to discourage urban sprawl, especially in the GTA. The State of Oregon has developed a land use planning process that might be adaptable to Ontario. Its "urban growth boundary" process seeks to identify and separate urbanizable land from rural land and establishes criteria under which rural lands can be classified "urbanizable". The process requires the development of urban areas before urbanizable land is converted to urban uses and gives priority to the retention of Class 1 farm land and to the minimization of adverse environmental and energy consequences.[34]

In addition, the province should encourage the construction of smaller, more energy efficient, and affordable homes. We suggest an effort to develop and commercialize, in collaboration with architects and builders, an affordable home programme that seeks to make 1,000 square foot or less homes, costing $60,000-100,000, attractive to the public, "infilling" land in Metro and other urban centres around the province.

Such a model for this kind of house has already been developed by Witold Rybczynski at McGill University in Montreal, the *Grow Home*. About 10,000 visitors viewed the Grow Home when it was on display on the campus, attracting mostly people looking for affordable housing alternatives to apartments. Asked if they were ready to live in a house smaller than 1,000 feet, 75 percent said yes, and 69 percent said the Grow Home was a good buy. The chief obstacle to smaller houses is not the consumer or the builder, but municipalities that resist the idea of allowing the subdivision of land into smaller plots, because they sadly view smaller, less expensive homes as a threat to property values and community status.

Fuel Switching Strategies

Restrictions are needed on the use of electric resistance heating, furnaces, and water heaters in new residential construction, to encourage maximum penetration of natural gas (or oil) heating in new buildings. Regions of the province that do not have access to natural gas supply should be exempted from any such restrictions, but in such regions every effort should be made by utilities to advance the potential for solar passive heating, solar water heating, and high efficiency ground source heat pumps that have seasonal efficiencies in excess of 200 percent.

Initially, the government can restrict the use of electric resistance heating in buildings such as social housing that it funds, and recently it moved to do so. Looking beyond its own strategic procurement policies, however, the province will need to develop other strategies to influence the market. One option, for instance, would be to require a hook-up fee for electric resistance heating. B.C. Hydro, for instance, has submitted a rate submission that would establish a residential electric space heating connection charge ranging from $650 for apartments to $1,150 for single family homes.[35] There is no reason why a similar scheme couldn't work in Ontario. Another option, discussed in Chapter 8, would be amendment of the <u>Power Corporation Act</u> to allow Ontario Hydro to operate in gas territories and to switch heating from electric to other fuels.

Renewable Energy Strategies

The best way to encourage the wide variety of renewable technologies, ranging from advanced windows to passive solar heating design, is to require new buildings to become progressively less energy intensive over time. Such a regulatory policy will stimulate a significant market for these technologies and designs because they will become the most cost effective means of compliance.

A variety of interim strategies can also help. Strategic procurement by government when it funds the construction of new buildings can expand the market for renewables. However, the creation of an artificial fad in the absence of a supporting regulatory and market strategies will ultimately lead to failure when, for one reason or another, government officials turn their attention to some other fad.

Utilities should be encouraged to lease solar hot water heaters. Niche markets such as outdoor swimming pools are a ready place to start.

Finally, all new residential construction should be required to be "solar ready", with the installation of tubing between the roof and the basement mandated by a future modification to the provincial building code. The incremental cost of installing such tubing in frame construction is likely to be minimal and will make the later retrofit of solar heating panels more cost effective.

2.7 Economic and Social Implications

The measures discussed in this section will make housing more expensive, but they will reduce annual operating costs, in most cases paying back the home owner during a reasonable period of time especially since Ontario Hydro's rates are steadily rising, while allowing Ontario Hydro to avoid the expense of new capital construction by postponing new generation further into the future. Nonetheless, at a time when home buyers are seeking affordable homes, home builders are likely to resist new regulatory measures that add to their costs and widen the price gap between existing and new homes. Furthermore, low income home owners or renters are likely to be hard hit by Ontario Hydro's rate rises, not to mention subsequent rises that will eventually be necessary to pay for the utility's energy efficiency initiatives in the years ahead.

ENERGY TRANSFER FEE. One way to redress this issue would be to levy an energy transfer fee—similar to the land transfer tax—on the *resale* of homes (first sale of new homes would be exempted). The level of tax would be proportionate to the floor space of the house and its relative efficiency (energy consumed per unit of floor space). The assessment would be linked to the energy efficiency rating system, and an energy audit would be required as a condition of sale. The revenues collected would be held in "escrow" for the home buyer to use for energy retrofit measures up to one year within purchase of the home. After that period the funds would revert to the government.

LOW INCOME WEATHERIZATION PROGRAM. Energy costs account for a larger proportion of the family budget of a low income family, and especially for those living in electrically heated homes, the rate rises that are coming are likely to be extremely regressive. Ontario, therefore, should establish a low income weatherization programme like the 15-year old federal programme in the U.S. The Wisconsin and Minnesota versions of the federal programme would serve as good models, since those states have cold climates, and because the weatherization protocols they have developed have managed to achieve energy reductions in the 15-to-20 percent range at a modest cost.

The programme would be a decentralized initiative, with utility funds being channeled through a provincial agency on a block grant basis to municipalities that have organized programs with the considerable participation of community and neighborhood organisations. The province's role, apart from funder, would be to develop a rigorous, but flexible weatherization protocol to ensure maximum, but cost effective energy reductions and to provide training programs and materials for public eduction as well as technical training of weatherization crews.

ENERGY EFFICIENCY MORTGAGES. To further improve the home buyer's motivation to purchase an energy efficient home, the province, working with the utilities and major mortgage lenders, would establish an energy efficiency mortgage programme that would provide a number of financial incentives to the buyers of energy efficient homes. For instance, since monthly house payments are lower in the energy efficient house, the banks would be able to lower the income requirements for buyers of such homes, increasing the affordability of home purchases. Such mortgages have been available in the U.S. for many years, though due to the lack of uniform home energy ratings, they haven't achieved significant market penetration there.[36]

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CHAPTER 3—COMMERCIAL SECTOR

"No major breakthroughs are expected in lamp technology in the next decade."
Ontario Hydro report (1986) on commercial conservation, four years prior to $5 rebate offer on compact fluorescent lamps

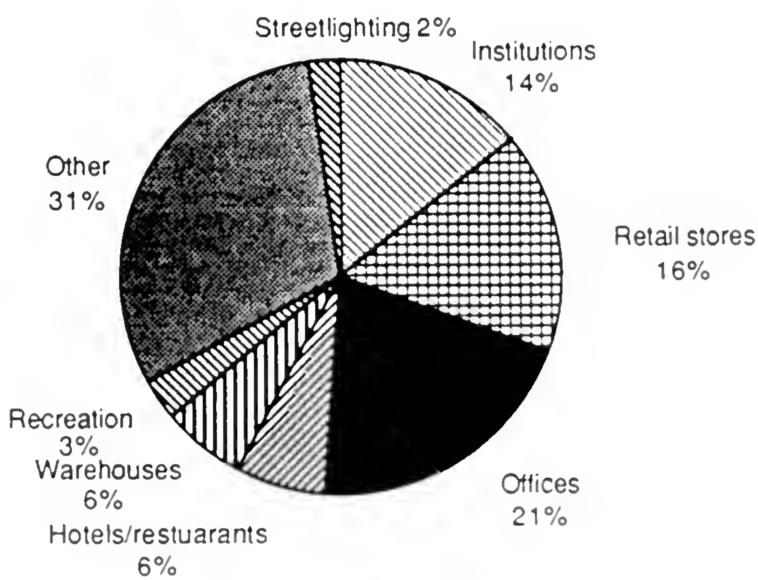
3.0 Introduction

There are approximately 240 million square metres (m^2) of commercial floor space in Ontario, including a wide variety of types, with offices accounting for the largest share of total floor space, followed by warehouses, educational facilities, and retail stores. All types of buildings together used about 643 petajoules (PJ) in 1988, or about 17 percent of the province's total energy. The commercial sector's share of Ontario's energy use is low compared with other countries, a reflection of the high energy intensity of the province's industry and transportation. Commercial energy use is forecast to grow at the average annual rate of 1.8 percent by 2005, driven mostly by an average annual growth in floor space of 3.4 percent.[37]

3.1 Profile of CO_2 Emissions

In 1988, Ontario's commercial buildings produced about 21.2 megatonnes (Mt) of CO_2 emissions, 13 percent of the province's total. Commercial buildings accounted for the lowest share of CO_2 emissions of the four energy end-use sectors.

Commercial CO2 Emissions by Sub-sector, 1988



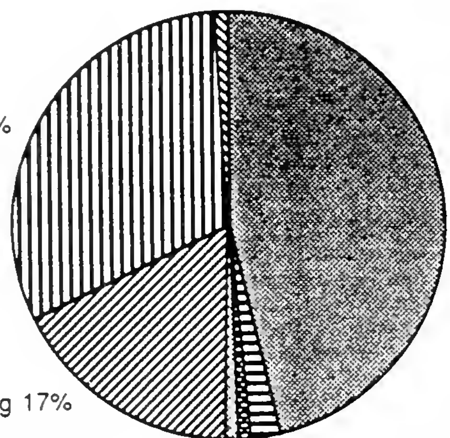
The end uses that predominate in this sector insofar as CO_2 emission are concerned are space heating, office equipment or "plug load", and lighting. Most of the space heating, about 79 percent, is fueled by natural gas, while all the other major end uses consume electricity. Indeed, commercial buildings are unique because they use the highest proportion of electricity

of any end use sector, and that use occurs primarily during the peak electricity demand period of the day when Ontario Hydro's coal-fired power plants typically provide from half to three-quarters of the province's peaking energy mix. As a result, over half of the CO_2 emissions from commercial end uses can be attributed to coal-fired electricity generation, mostly from consumption of energy by lighting and office equipment.

Because of the predominance of electricity in this sector, emissions are likely to be higher than reported here, since over half of the commercial sector's energy use comes from electricity, much of which is supplied during the peak demand period of the day. For instance, assuming that two-thirds of the commercial sector's electricity demand is met by peaking generation and two-thirds of peaking generation is provided by coal, the commercial sector's total CO_2 emissions would be closer to 30 Mt.

Electricity is expected to increase its share of commercial end use by 2005, largely due to the rapid growth in use of plug load—especially office equipment such as personal computers, laser printers, plotters, photocopiers, and fax machines—and increasing cooling demand, which reflects in part the larger internal heat created by plug load, as well as increasing exterior summer temperatures caused by air pollution and the urban heat island effect.

CO2 Emissions by Commercial End Use, 1988



3.2 Profile of energy intensity trends

Since 1973, energy use has fallen from about 2.6 GJ/m² of commercial floor space to about 2 GJ in 1988, a drop of about 23 percent or 1.7 percent per year. This remains high, however, compared with other industrial countries. Commercial energy intensity in the U.S., for instance, averages about 1.1 GJ/m², or about 1.2 GJ/m² in the northeastern states, whose climate isn't too different from southern Ontario's climate.[38]

The decline in commercial building energy intensity has been due mostly to the addition of new buildings that have overall lower intensities than the existing stock, with new office buildings in 1986 using 1.6 to 1.7 GJ/m² according to Ontario Hydro.[39] With new building intensities today approaching 1.4 GJ/m², a gradual decline in energy intensity in this sector is expected to continue. The Ministry of Energy estimates that energy intensity in the office

building stock will decline .8 percent per year from 1988 to 2000 or a total of eight percent, about half the rate of decline that occurred during the period 1973-1988.

3.3 Opportunities for CO_2 Reduction

There is considerable opportunity for CO_2 reductions from existing and new commercial buildings from a combination of efficiency savings, substitution of natural gas for electricity, and use of renewable energy technologies. The efficiency savings would come from the incorporation of state-of-the-art heating, cooling, lighting, ventilation, and energy management control systems into new building design and retrofits. The development and rapid expansion of commercial markets for cogeneration would lead to natural gas assuming a share of the electricity demand for buildings. The use of renewable technologies, such as daylighting, advanced windows, and solar water heating, could reduce energy use in buildings even further.

EFFICIENCY POTENTIAL. The energy conservation potential in Ontario's commercial buildings has been extensively studied. Ontario Hydro conducted an assessment in the mid-1980s which identified about 11,000 gigawatt-hours (GWh) of potential electricity savings against a forecast assumption of 58,000 GWh in 2000, about a 19 percent reduction.[40] Many new technologies have been commercialized since that study, however, notably in the lighting area. For instance, none of the following were available in Canada in the mid-1980s: reflective luminaires, dimming ballasts, occupancy sensors, or compact fluorescent lamps.

A more recent study of the potential of electricity conservation to avoid the installation of scrubbers to control acid gas emissions found a total of 16,000 GWh against a frozen efficiency forecast of 52,000 GWh, a 31 percent reduction, with all of the measures costing less than 4¢/kWh.[41] Constraints on the study included limitation of efficiency measures to ones that had been evaluated in a previous study conducted by the same firm several years earlier, thus eliminating new technologies. Furthermore, technologies and efficiency measures were assumed to be taken up in buildings only at the normal rate of turnover of equipment, hence, replacement of iron core ballasts with electronic ballasts in lighting, for instance, was not assumed to take place until the old ballasts had reached their useful 40,000 hour life time.

The most comprehensive assessment of the CO_2 reduction potential in buildings in North America has been conducted by the U.S. Office of Technology Assessment (OTA), which found that under a "tough scenario" emissions could be reduced by 32 percent by 2005 from 1987 levels in residential and commercial buildings altogether.[42] The costs for the tough measures would range between $53 billion net savings per year (i.e., equipment costs minus fuel savings) to net costs of $7 billion per year. The accompanying table describes OTA's "tough" measures for commercial buildings.

Table 3 (a): Tough Measures for Commercial Buildings in OTA Model

Operation in existing stock:	
Building retrofits	40% savings by 2000
High efficiency lighting	High efficiency bulbs, net 12% savings (80% of 15%—assume 20% market already)
New Investments:	
Shell efficiency of new buildings	New buildings 75% more efficient than average
HVAC equipment:	
Gas space heat	All 92% efficient, move market share of gas heat pump forward by 5-10 years
Electric space heat	Replace 50% of new electric resistance heating space heat with heat pump
Air conditioning	Adjust variable speed drives and economics, net 20% savings
Cogeneration	0.64 quad by 2015

Water heaters............................Replace 100% of new electric water heaters with heat pump water heater
Lighting....................................Combination of high efficiency bulbs, ballasts, etc.; net 60% savings in new, 50% in replacements
Electronic office equipment..........65% savings from improved technology and 40% in reduced idle time; total 80% savings

Accelerated turnover/new technology:
HVAC equipment.........................Gas heat pump COP of 1.4 by 2015; electric heat pump COP of 2.4 by 2015; heat exchangers yielding 28% AC savings
Cogeneration..............................-.96 quad by 2015 including fuel cells and improved chillers
Water heaters............................Replace gas water heater with 80% efficient prototype

New office buildings constructed in Ontario typically achieve a total energy intensity of 1.0 to 1.4 GJ/m^2 today, but they can readily achieve 0.7 GJ/m^2, half the present intensity of the office building stock.[43] The improvements in efficiency are made possible by:

- lighting technologies such as high efficiency fluorescent lamps, replacement of incandescent lighting with compact fluorescent lamps, reflective luminaires, electronic ballasts, and occupancy sensors and daylight dimming controls can achieve 75 percent reductions in energy use;
- installation of mid- and high-efficiency furnaces, regular boiler tune-ups, use of turbulators and improved burners;
- upgrading unitary air conditioning systems, downsizing chillers, given the reduced internal heating load from lighting, and installation of "free cooling" economizers that reduce compressor running time;
- a variety of upgrades to the ventilation equipment. such as installation of variable air volume systems that vary the flow and volume of air according to building demands.

Case studies show that both private and institutional office buildings are being constructed in Ontario today that economically achieve .7 GJ/m^2. For instance, the Ottawa Courthouse and Registry, housing law courts and offices, was designed to include features such as walls and roof insulated to R-20, triple pane insulated glass, efficient lighting technologies, and a heating, cooling, ventilation system that uses variable air volume and free cooling economizers. The building consumes .4 GJ/m^2 (not including plug load).

A recent retrofit of the Lorne Mitchell Office Building in Metro Toronto will reduce energy consumption from .9 to .7 GJ per m^2 (including plug load), or 25 percent, using high efficiency lighting and motors, heat recovery from exhaust air, and central heat pumps for perimeter heating. The retrofit cost 1.7¢/kWh amortized over 30 years.

Much higher reductions are being reported in the U.S. by a number of firms that specialize in commercial retrofits. For example, the Natural Resources Defense Council rehabilitated an industrial loft building space for new offices in 1989 in New York City, achieving reductions from pre-renovation energy use in lighting energy intensity of 80 percent, cooling energy intensity of 50 percent, and heating energy intensity by 70 percent. Electricity use overall was reduced 50 percent (including plug load). The significant reduction in lighting energy intensity was achieved by combining daylighting with a continuous dimming system that adjusts lighting to the amount of daylight present.[44]

FUEL SWITCHING POTENTIAL. A comprehensive assessment of cogeneration possibilities in Ontario reported just a few years ago a technical potential in the commercial sector of 2,200 MW in Ontario, with 570 MW economically achievable.[45] Even more economic opportunities exist today, however, due to technological advances and modestly higher buy-back

rates. There is potential for CO_2 reductions because natural gas cogenerated electricity can displace peaking energy that comes mostly from coal.

Despite the fact that Ontario Hydro foresees only 85 MW of potential non-parallel commercial cogeneration in the next 10 years, Ontario companies are already seizing the business opportunities.[46] Atlas Polar, for instance, has developed a 250 kW unit using American and Canadian components, and it is presently testing nine demonstration units that have a combined electrical/thermal efficiency of 70-80 percent. The company has identified about 500 MW of technical cogeneration potential in the 1 kW to 1 MW range, and it is seeking to capture a quarter of the market with its equipment by 2000. The unit will sell for $1,100 kW installed and will pay back in five years.[47] Once the 250 kW model reaches the market, the company plans to develop 150 kW and 350 kW units.

Larger cogeneration units for office buildings, which do not need much heat during warmer months of the year, will become practical once absorption chillers are introduced into Canada, a technology that can take the heat produced by a cogeneration unit and turn it into space cooling.

RENEWABLE ENERGY POTENTIAL. The technologies with the greatest near term potential include active solar hot water service for buildings, and passive solar technologies such as high performance windows, daylighting (coupled with dimming ballasts to attenuate lighting), and thermal storage. District cooling with lake water is also reviewed.

Between 1984 and 1988 Energy, Mines and Resources Canada (EMR) supported the installation of over 170 commercial solar water heating systems across Canada, and cost and performance data on these projects now indicates that the systems are delivering service close to the predicted values. A recent study of the technically feasible market for active solar in Canada indicates that commercial solar hot water could replace 8 PJ of load by 2010 in Ontario, or about 20 percent.[48]

An Ontario company, Solcan Ltd., has identified several niche markets with good potential. For instance, it is marketing its commercial hot water system to nursing homes, which have continuous need for hot water for laundry, dish washing, and bathing. Solcan's system provides 10-to-25 percent of the hot water in such installations, or about 160 GJ for each nursing home. Since there are about about 450 such complexes in Ontario, the technical potential for the system is close to 1 PJ.

Virtually all new commercial buildings could incorporate passive solar technologies. One Ontario Company, Conserval Engineering, Ltd., has been marketing for over a decade an innovative building structural component, Conserval Wall, which circulates fresh air in a solar heated wall and distributes the air throughout the building. The technology is well suited to large, open buildings such as gymnasia and warehouses and provides up to 100 percent of the space heating needs.

A recent EMR study estimates a large passive potential in Ontario, with 56 PJ of technical potential achievable by 2010 in existing and new buildings. Under the "reasonably achievable" scenario, high performance windows (RSI 3+) will be used in 22 percent of new buildings, daylighting in 35 percent, with a small contribution by thermal storage systems such as PCM wallboard.[49]

Another potential renewable energy source is Lake Ontario. Toronto's downtown district heating system, which extends from Harbourfront up to Queen's Park, is not presently used for cooling, but pumping 4°C water from about 70 metres of depth from Lake Ontario could meet air conditioning loads during the summer. Dubbed "Freecool", since up to 95 per-

cent of the energy presently used for chillers would be avoided, this system could displace about 200 MW of peak summer demand, or the equivalent of about 7 PJ, assuming 1,000 hours/year operation. Because Lake Ontario's surface water cools to 4°C each winter and then sinks, "Freecool" is essentially a renewable resource. The City of Toronto has already commissioned preliminary studies, including an environmental assessment.

In sum, recent studies have identified 71 PJ of technical renewable energy potential in Ontario. Companies based in the province already have products for this market and are positioned to expand to meet additional demand should government and utilities encourage renewables.

3.4 Measures to Reduce CO_2 Emissions

The economically attractive measures assumed to reduce CO_2 emissions are described in detail in Appendix C. They include the following:

RETROFIT TARGETS FOR EXISTING BUILDINGS:

Efficiency scenario:

- Improvements in thermal envelope and furnaces reduce heating energy in 50 percent of the building stock by....20%
- Reduction in cooling energy in 50 percent of the building stock by....20%
- Level Three lighting retrofits reduce electricity loads in 75 percent of building stock by....60%
- Reduction in ventilation energy by retrofitting efficient motors in 50 percent of building stock by....25%
- Reduction in water heating in 50 percent of building stock by....25%
- Reduction in cooking energy in 50 percent of building stock by....20%
- Reduction in plug load energy in 100 percent of buildings by....20%*

Fuel switching scenario:

- Switch from oil to gas space and water heating by....50%
- Switch from electricity to gas space and water heating by....5%

Renewable scenario:

- Retrofit commercial solar water heating....2 PJ
- Retrofit passive solar heating technologies, such as advanced performance windows....5 PJ
- Implement Freecool in Toronto district heating system, assumes operation of 1,000 hours per annum....7 PJ

*A note about plug load: it is the fastest growing component of energy use in commercial buildings. The U.S. Office of Technology Assessment, however, estimates that the energy used by office equipment may be reduced by 80 percent over the next 15 years if investments in new technology are made, with 65 percent of the savings from new technology (such as the incorporation of laptop computer technologies into desktop computers) and a 40 percent reduction in idle time.

ENERGY INTENSITY TARGET FOR NEW BUILDINGS:

It is assumed that the average energy intensity of new buildings declines 50 percent from the average level of the 1988 building stock, as given in Table 1. Hence, office building stock constructed 1988-2005, for example, would average .7 GJ/m2 or 18 kWh/ft2 in 2005. Furthermore, fuel shares given in Table 9 are assumed, with solar assuming 30 percent of the space and water heating loads, and electricity declining from 13 percent (1988) to 5 percent of the space heating share, and from 25 percent (1988) to 10 percent of the water heating share.

As a result of the measures described above, CO_2 emissions are reduced by 46 percent from 1988 levels. Much of the reduction indicated is due to the decline in electricity's share of building energy—from 58 percent to 53 percent in existing buildings, for instance—keeping

electricity demand to a 20 percent rise (while floor space increases by 52 percent), and (ii) the decline in the CO_2 emissions rate of electricity (see Appendix F), which is less than half the emissions rate for 1988. Since the commercial sector uses a higher proportion of electricity than any other sector, the lower electricity emission rate has the most impact in this sector. The results are summarized in Appendix C, Table C-12.

3.5 Barriers to Achieving Measures

Despite the great potential for energy conservation in commercial buildings, this sector has been slow to respond to the rapid pace of energy efficiency advances. This failure is a market problem, rather than a technology problem. Energy efficient lighting, heating and cooling, motors, energy management controls, and building envelop technologies are commonplace in the U.S., Japan, and Europe, but not Ontario. Reasons for the failure include:

- the fragmented character of the commercial building market leads architects, engineers, and contractors to seek to minimize their liability and first costs, thereby discouraging technological innovation and the incremental capital investment needed to reduce the energy costs associated with the operation of a building over its lifetime (which can approach the initial original cost of the entire building);
- many buildings are renovated or constructed on speculation by builders who are understandably obsessed with first cost and lack interest in long-term operating cost of the building;
- the problem of "split incentives", i.e., building owners have little financial incentive to invest in energy efficiency retrofits, since they pass their energy costs on to the individuals and firms that lease or rent space, who in turn pay a share of energy costs proportional to their floor space, not the actual energy they may consume;
- credible information on commercially available technologies often does not get into the hands of building engineers and operators or utility demand-side management managers;
- the rapid growth in office equipment, especially personal computers and their accessories, has accelerated "plug load" in the last five years;
- in the case of cogeneration and renewable technologies, negative attitudes and high initial capital costs tend to discourage investment in these energy forms.

Exacerbating these market barriers are outdated or non-existent provincial building code standards in many areas of energy efficiency; a dearth of energy efficiency demonstrations that combine a variety of advanced lighting, heating, building envelope, and control components into an overall system; and lax or non-existent municipal oversight of energy practices in the building sector.

3.6 What Ontario Can Do

The province can achieve the measures needed to reduce CO_2 reductions in this sector can by:

- amending the provincial building code to require more thermally efficient building envelopes and to encourage more use of renewable technologies in building design;
- establishing financial incentives and disincentives to spur building owners to construct and maintain energy efficient buildings.
- regulating the efficiency of commercial lighting, refrigeration, furnaces, and water heaters under the Energy Efficiency Act;
- promoting policies that encourage commercial cogeneration and renewable energy;
- education programmes for architects, engineers, and building managers.

Efficiency Strategies

The province should take steps to ensure that the opportunities for energy efficiency in new construction are not lost, by embarking on progressive amendments to the provincial building code to establish prescriptive and performance standards for all categories of commercial buildings and by pursuing minimum efficiency regulations for commercial heating, cooling, and lighting equipment. In addition, the province should undertake a major programme to retrofit existing provincial and municipal buildings.

ADOPT ASHRAE 90.1 IN THE PROVINCIAL BUILDING CODE. With respect to the provincial building code, the province should move immediately to implement ASHRAE's commercial standard 90.1. In 1989, the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) and the Illuminating Engineering Society of North America published a new standard, ASHRAE 90.1, that sets minimum requirements for the energy efficient design of new commercial buildings. It specifies basic engineering requirements for electric power, lighting, HVAC, building envelope, water heating, and energy management of a variety of building types and U.S. climate regions.

Even though many elements of the standard reflect 5-to-10 year old technologies, buildings constructed in accordance with ASHRAE 90.1 are expected to use 30-40 percent less energy than present building stock average. Several cities, including Seattle, San Francisco—and in March, 1991, Toronto—are in the process of incorporating the standard into local building requirements.

The applicability of ASHRAE 90.1 to Ontario would require calibrating the code to the province's weather regions and its adapting to Canadian building practices. Implementation of the standard will lower energy intensities of new office buildings to about 1 GJ/m^2, about half way towards the .7GJ/m^2 cumulative target needed in new office buildings 1994-2005 to achieve the CO_2 reduction measures indicated above.

Since the ASHRAE standard is not particularly strong in the lighting area, revisions to the building code should incorporate lighting standards such as those found in the California Building Code, Section 2-5342.[50]

The provincial building code should also provide that the electrical system in new buildings be "sub-metering" friendly, allowing for flexibility in system layout so that individual offices can be easily sub-metered on each floor. This would be a prelude to utility reform that requires sub-metering of commercial customers, so that high users of energy, such as firms that have high plug loads, pay their fair share of energy costs.

DEVELOP A HOOK-UP FEEBATE PROGRAM FOR NEW BUILDINGS. The province should also implement a feebate programme that requires building owners to pay fees for electricity and natural gas hook-up, the amount of the fee proportional to the amount of energy the new building is designed to consume relative to a performance standard. If the building owner designs an efficient building, the owner would receive a rebate, again the amount proportional to the savings relative to the standard. The program would be revenue neutral, with provincial administrative costs being paid out of fees collected.

The feebate performance standard would be based on life-cycle cost analysis, which would assess the full costs and benefits of an energy system, discounted to present value, including the capital investment, full projected lifetime operating and maintenance expenditures, as well as the projected environmental and other external costs and benefits of the system. The province should develop a life-cycle analytical tool that it and municipal governments can use to evaluate new development projects, as well as retrofit programmes.

The feebate standard would be based on greater energy efficiency than the building code standard, and it would anticipate changes in the building code by several years. In this way, the market—and builders—would be encouraged to explore new technologies, and be rewarded for doing so, several years before the province requires the energy efficiency gains made possible by such technologies in its building code.

As a model, the province should examine the Massachusetts hook-up fee program (for electricity only and buildings greater than 50,000 sq. ft.), which is likely to become a state law this year.[51]

RETROFIT EXISTING GOVERNMENT OWNED BUILDINGS. The province should undertake a major effort, funded by utilities at their full avoided cost, to retrofit government owned buildings in Ontario with high efficiency heating and ventilation systems, lighting, motors, and other equipment. Toronto has already begun such an effort with respect to its own building stock, coordinated by its energy efficiency office, and Ottawa may also be developing a similar initiative soon. Local municipal efforts such as these would benefit greatly from a province-wide strategy led by the Ministry of Energy, involving training programmes, coordinated funding from utilities, and strategic procurement of advanced energy efficiency, cogeneration, and renewable energy technologies.

REGULATE ENERGY EFFICIENCY OF COMMERCIAL EQUIPMENT. The province has yet to use the Energy Efficiency Act to regulate commercial equipment. It should begin to do so, starting with commercial lighting fixtures, ballasts, and lamps, examining what Massachusetts has already done as one possible model.[52] One promising route would be to set performance standards for luminaires and lighting systems as a whole, rather than (or in addition to) prescriptive standards for each component. While ASHRAE 90.1 goes a step in this direction, presently available technologies should permit much stronger lighting efficiency regulation. California is one of several states that has recognized this and has already adopted stronger lighting standards in its building code.[53] Since the potential for CO_2 reduction from improved end use lighting are so dramatic, the province should give high priority to this initiative.

Fuel Switching Strategies

Recent studies indicate that attitude and economics are the primary barriers to the development of cogeneration in Ontario.[54] The attitude in the private sector is that "electricity is not our business", reflecting the centralized position that Ontario Hydro occupies in the minds of business people. This attitude is reinforced by Ontario Hydro's lack of interest in commercial cogeneration. Though it could be a good load displacement strategy, the commercial efficiency branch of Ontario Hydro is prevented by corporate policy from exploring this option further.

Building owners are reluctant to become power producers also because they are looking for short three year or less payback on their investments. Cogeneration systems, on the other hand, may take five years or more to pay back. The exception may be institutional building owners, such as schools, governments, and hospitals, who tend to take a longer-term perspective on capital investments.

A variety of financial incentives could be useful in encouraging cogeneration. A fast three year write-off for cogeneration equipment is already available. Additional measures might include investment grants to shorten the payback period, investment tax credits, and loan guarantees. The best stimulus, however, would be an Ontario Hydro parallel generation "buy back" rate that truly reflects the cost of new generation supply and its environmental costs.

Renewable Energy Strategies

The same barriers apply to renewable energy technologies, only there are even more negative attitudes to overcome. Solar technologies are often viewed as contraptions of the sixties and seventies "granola" generation, not quite realistic today. This attitude is likely reinforced by the fact that most of Ontario's solar companies failed during the 1970s, leaving no one to service the many installations that were made.

The province's remaining solar companies emphasize the importance of avoiding the pitfalls of previous government policies that were intended to promote solar but inevitably did them in. The emphasis on cost cutting to make the technologies more competitive left many firms bankrupt. The federal PUSH programme comes under particular criticism, since design contracts were let to large firms that had little solar experience, so they tended to err on the side of over capacity, leading to many installations that were over sized and over priced. The image of uncompetitiveness was created, in part, by the very programs seeking to promote solar.

What is needed to revitalize the industry in Ontario is, first, high profile demonstrations that help building owners regain confidence in the technologies, and second, financial and regulatory policies that promote solar. One promising approach would be for the province and utilities to set up a leasing programme that spreads the initial capital costs of the system over an appropriate period of time. On the regulatory side, the proposed hook-up fee programme for new buildings could include a credit for the use of energy derived from renewable sources.

The province is fortunate to have a number of consulting firms that specialize in solar technologies. The Ministry of Energy, as it studies the potential for renewable energy in the province, should utilize the knowledge and experience these firms have and help build the design and engineering base needed for an expansion of this industry in Ontario.

3.7 Economic and Social Implications

Building owners are likely to object that the energy hook-up fee programme makes their new commercial space less competitive with existing space, since somewhat higher capital costs will be associated with more energy efficient buildings. There are several ways, however, that costs might be equalized between new and old buildings, while encouraging greater energy efficiency in existing buildings. One option would be to raise commercial electricity rates, which would benefit lessees of new, more energy efficient commercial space compared with lessees of older, less energy efficient space. Another option might be to require lessees of existing space to pay for sub-metering when a new lease is signed.

The public is most likely to be affected by policies in the commercial sector from the way these policies impact on buildings owned and operated by institutions such as schools, colleges, public recreational facilities, and hospitals. Since efficiency, cogeneration, and renewables are likely to lower the long-term operational costs of these facilities, the public will surely benefit.

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"The elevated section of the Gardiner-Lake Shore Expressway should be taken down, in a phased programme, over the next 20 years."
Recommendation of the Royal Commission on the Future of the Toronto Waterfront, Hon. David Crombie, Commissioner

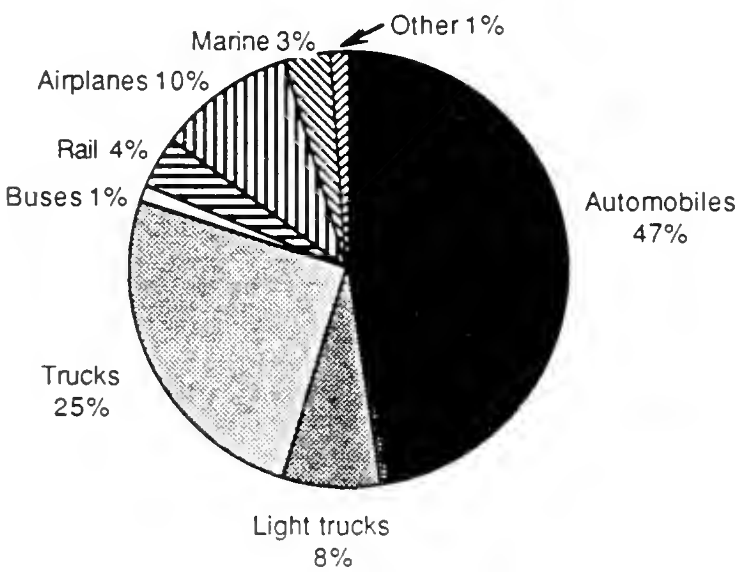
4.0 Introduction

There are approximately 4.6 million passenger automobiles and 1 million trucks registered in Ontario. Together with other transportation modes, including public transit, air planes, and ships, Ontario's transportation sector consumed a total of 675 petajoules (PJ) of energy in 1988, about 18 percent of the province's total. The Ministry of Energy forecasts the total number of passenger vehicles to increase to 6.5 million by 2005.

4.1 Profile of CO_2 Emissions

In 1988 Ontario's transportation sector produced about 46.3 megatonnes (Mt) of CO_2 emissions, 28 percent of the province's total. Almost all of the emissions comes from the consumption of petroleum. Passenger automobiles account for almost half of transportation's carbon emissions and about 13 percent of Ontario's total. Motor vehicles altogether account for about almost a quarter of the province's carbon emissions.

Transportation CO2 Emissions by Mode, 1988



Ontario's automobiles each annually consume an average of 64 GJ of energy and each emits annually 4.7 tonnes of CO_2. Of all Ontario's end use sectors, transportation is the most carbon intensive, producing about 69 tonnes of CO_2 per MJ of energy consumed.

By 2005, CO_2 emissions from Ontario's transportation sector are expected to rise 29 percent, according to Ministry of Energy forecasts. The estimate assumes there will be modest improvement in the fuel efficiency of motor vehicles over the period, about 11-15 percent—

less than one percent per year—while the average distance vehicles are driven will decline about 3 percent by 2005. Modal shares of automobile and public transit, as well as automobile load factors remain relatively unchanged in the forecast. Natural gas use is estimated to rise ten fold, though it still remains a minute share of the motor fuel market. After 2000 alcohol blends begin to play a role, and by 2005, 10 percent of gasoline has a 10 percent blend.

The primary factor driving the rise in fuel use and carbon emissions is the rise in the total stock of vehicles, a 2.1 annual average change reflecting population growth.

While reducing CO_2 emissions is the theme of this paper, it should be noted that motor vehicles produce a variety of other emissions that contribute to global warming directly or indirectly.[55] They include:

- chlorofluorocarbons (CFCs) used in automotive air conditioning;
- nitrous oxide (N_2O), a greenhouse gas that is 200 times more powerful than CO_2 on a molecule basis;
- methane (CH_4), a greenhouse gas which is about 20-40 times more powerful than CO_2 (emissions are associated particularly with natural gas vehicles);
- hydrocarbons (HCs) and nitrogen oxides NO_X, which react under the influence of heat and sunlight to form tropospheric ozone, a greenhouse gas;
- carbon monoxide (CO), which neutralizes other atmospheric gases, such as hydroxyl (OH), that serve the important purpose of limiting the life span of other greenhouse gases, such as methane, in the atmosphere.

Scientific concern about CO has recently emerged.[56] This pollutant is not only poisonous and a serious health hazard, but evidence suggests that a gram of CO has a greater influence on global warming than a gram of CO_2, for two reasons. First, CO increases the lifetime of atmospheric methane by 20 percent by neutralizing hydroxl. Second, CO eventually converts to CO_2. The overall impact of a molecule of CO, may be 2.2 times that of a molecule of CO_2. Recent evidence of a decline in hydroxl in the northern hemisphere has amplified scientists' alarm about CO.[57] Some of the measures proposed, such as greater use of ethanol blends, would have the added benefit of reducing emissions of CO (and the formation of ground-level ozone), as well as CO_2.

The high carbon intensity of Ontario's transportation sector and the fact that motor vehicle emissions contribute to global warming in many other ways (not to mention air pollution problems generally) suggest that this sector should receive a high priority in the province's global warming strategy.

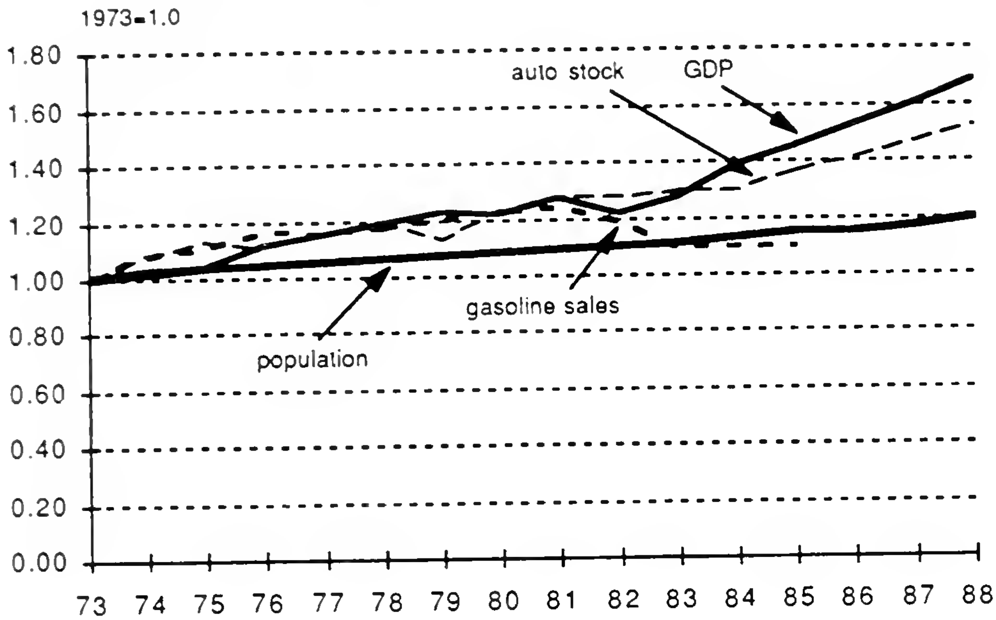
4.2 Profile of Energy Intensity Trends

New vehicle purchases and driving habits in recent decades have been strongly related to two post-World War trends: the baby boom and growth of the two-income household. In Canada, since 1970 the proportion of the driving age (16 or older) population has been increasing, and the female labour force has been climbing faster than the male labour force. The result has been a more rapid increase in the labour force in the 1970s than the 1960s and the growth in multiple-car households.

These trends have helped promote a steady increase in the number of autos in Ontario. Indeed, Ontario's personal auto stock has been climbing faster than households over the 1961-1981 period. Since the mid-1970s there have been more personal autos in Ontario than households. In addition, the total distance Ontarians drive their cars, both for personal and commercial uses, has increased steadily, primarily because urban centres have sprawled into suburbs, while the average mileage each per person drives their car has also risen over the period.

These socio-economic trends produced steadily rising gasoline consumption in the 1960s. The price effects of the 1973 and 1981 OPEC oil shocks, however, coupled with new Canadian road taxes, and U.S. and Canadian Corporate Average Fleet Economy (CAFE) standards caused gasoline consumption to level off in the late 1970s and to decline in the early 1980s, as more fuel efficient cars went on the road.[58]

Auto Energy vs. Economic Trends, 1973-1988



Until the early 1980s energy use in transportation was closely correlated with the province's GDP. In 1980, when Canada's voluntary CAFE standards took effect, gasoline use dropped and decoupled from GDP. During the 1980s, although the total number of motor vehicles registered in the province has been increasing, gasoline sales have remained relatively constant. (See accompanying graph.) They will begin rising significantly once the fuel efficiency of the province's total car stock catches up with the fuel efficiency of new cars, whose mandated level has remained unchanged since 1985.

Unless oil prices rise significantly during the 1990s, these trends are not likely to abate without direct government intervention, and gasoline use, along with it transportation energy use, will begin rising inexorably.

4.3 Opportunities for CO_2 Reduction

Significant gains in the efficiency of transportation modes, especially the passenger automobile, have been made over the last 15 years, and technologies permitting use of cleaner alternative fuels have also been developed, commercialized, and are now in wide use in parts of the world. Recently, the Big Three North American auto makers announced a $100 million R & D initiative to commercialize a feasible, cost effective battery to permit electric cars to become commonplace after 2000. Much of the technology development is now being compelled by southern California's stringent vehicle emissions standards and rising public concern about deteriorating urban air quality throughout North America.

EFFICIENCY POTENTIAL. Wider employment in the 1990s of a variety of technologies now available in existing models or proven in prototypes could improve the average fleet economy of new automobiles from the present 8.7 litres/100 km to 6.7 litres/100 km, without degrading ride, performance, or capacity over 1987 levels, at an average cost of 14 cents per litre of gasoline saved.[59] Although the additional cost of a new car to the consumer would be about $1,000, the efficiency investment would pay the car owner back in three-to-five years depending on driving habits.

While auto manufacturers maintain that improved fuel economy means smaller cars, it appears that many of the new technologies are now being used to increase power and performance, while allowing the manufacturers to comply with U.S. Corporate Average Fuel Economy (CAFE) standards. Between 1988 and 1990, for instance, there was a four percent decline in the fuel economy of the passenger car fleet sold in the U.S., while horsepower increased by an average of 10 percent, and weight increased by six percent.[60] Assuming power and performance remain constant, however, employment of the technologies would increase fuel economy over time.

TABLE 4 (a): Impact of Fuel Economy Technologies on Cost and Fleet Average

	Consumers cost *(U.S.$)*	Annual cost *(U.S.$)*	Market share	Incremental efficiency of vehicle *(U.S.mpg)*	Cumulative EPA fleet Economy *(U.S.mpg)*
•Roller cam followers	$15	$2.06	37%	0.3	28.4
•Overhead cam engine	$74	$10.14	69%	1.19	29.6
•Intake valve control	$80	$10.96	75%	1.24	31.0
•Front wheel drive	$150	$20.55	23%	2.17	31.7
•4 valves/cylinder	$105	$14.39	100%	1.51	33.8
•Improved accessories	$29	$3.97	80%	0.4	34.3
•Aerodynamic improvements	$80	$10.96	85%	1.1	35.6
•Torque converter lockup & electronic emission control	$39	$5.34	75%	0.55	36.2
•Multi-point fuel injection	$67	$9.18	56%	0.89	36.9
•Engine friction reduction	$80	$10.96	80%	1.03	38.1
•Continuously variable transmission	$100	$13.70	45%	1.25	38.9
•Improved lubricating fluids	$22	$3.01	100%	0.27	39.3
•5-speed automatic overdrive transmission	$150	$20.36	40%	1.29	40.0

Note: 40 mpg = 5.8 litres/100 kilometres

The technologies that would most cost effectively improve fuel economy are those which reduce transmission weight (front wheel drive), boost engine horsepower (four valves per cylinder), lower engine inertia (overhead cams), optimize valve timing and lift for different speeds and loads (intake valve control), and reduce aerodynamic drag, all without reducing the size or performance of the car. The accompanying table describes the impact these technologies would have on fuel economy and cost.

In Canada, use of all the technologies described would add about $1,150 to the cost of a new car and about $160 to the annual operating cost of the car, mostly in financing costs. The technologies, however, would save about 435 litres of fuel annually, assuming 15,000 kilome-

tres average distance driven, that would otherwise cost about $260 annually at 60¢/litre. The net annual saving to the new car owner, therefore, would be about $100.

Even larger efficiency gains would be possible in the passenger car fleet were the public willing to accept smaller, lighter, and less powerful cars as second vehicles. While such cars may have more limited application, they would be very suitable for some purposes such as urban commuting and use. The question of safety concerns arise, however. The U.S. National Highway Traffic Safety Administration analyzed single-car crashes for 1970-1989 and found that in rollover crashes smaller cars had an increased risk of fatal injury of about a third, while in non-rollover crashes reduced car weight had little or no effect on the risk fatality.[61] Over the past 15 years, however, U.S. road deaths saw a 33 percent decline in the rate per vehicle miles, during a period when the average weight of vehicles declined by 1,000 pounds. It would appear that a combination of better engineering, seat belt use, and crackdowns on drunken driving can offset the safety risks associated with an increase in smaller, lighter vehicles on the road. Nonetheless, consumers may continue to be reluctant to purchase smaller cars.

Population and job densities also significantly affect automobile energy use and emissions. A landmark 10-year study by Peter Newman and Jeffrey Kenworthy provides excellent documentation as to the relationship between land use, public transit infrastructure, and energy consumption in cities.[62] They have gathered, analysed, and compared transportation and energy data from 32 cities around the world, including five Australian, 10 American, one Canadian (Toronto), 13 European, and three Asian cities. They found that the factors commonly thought to explain urban gasoline demand, such as income, city size, and fuel price, fail to explain differences among cities. Those factors which do explain such differences in gasoline demand, as well as per capita car use and public transit use, include density of population and jobs, parking supply, road supply, and other infrastructure indicators. Their main findings are that:

- great variation in per capita gasoline use exists among different cities, with the average American city consuming about twice as much gasoline as Australian and Canadian cities, three times the average European city, and 10 times the average "westernised" Asian city;
- differences in gasoline use correlate inversely with population density, i.e., higher uses of gasoline typically characterize lower density cities and vice versa;
- the provision of road supply is strongly correlated with total vehicle ownership, gasoline use, and virtually all other vehicle indicators used in the survey;
- a strong correlation exists between rapid rail public transport and lower private auto orientation and gasoline use.

Newman and Kenworthy's extensive statistical analysis leads to several important conclusions. First, land use policies that encourage higher population densities in cities are likely to lead to lower gasoline use per capita. Second, building more roads to solve congestion problems may only lead to greater auto dependence, congestion, and higher levels of gasoline consumption. As a corollary, however, congestion that is allowed to persist by limiting new road supply may serve as a useful means of encouraging people to switch to public transit and bicycles. Finally, rapid rail systems may be the only way to ensure higher, auto-competitive speeds for public transit, since buses and streetcars tend to get slowed in traffic.

Since Ontario is highly urbanized, with almost half the province's population living in the Greater Toronto Area (GTA), whether and how future growth and development is guided in these areas will significantly impact on future transportation energy use and CO_2 emissions. With policies to increase density in the GTA—particularly in Metro—and other urban centres, combined with initiatives to significantly expand public transit, especially rapid rail, the goal of

stabilizing vehicle kilometres travelled in these centres would be feasible, as presented by the analysis in Appendix E. Indeed, without such gains, urban air pollution is destined to worsen towards the year 2000, as reductions of pollutants such as NO_x, CO, and HCs bottom out from improved tailpipe controls under the new federal regulations.

FUEL SWITCHING POTENTIAL. Alternative fuels also hold great promise for carbon reduction in transportation. Natural gas, for instance, contains a third less carbon than petroleum fuels on an energy unit basis. In practice, however, estimating their greenhouse reduction potential is somewhat complicated, since a variety of factors may affect the overall energy balance of a fuel's production, distribution, and eventual end use.

Methane leakage may occur from well head to end use, for instance. Since methane is 20-30 times more potent as a greenhouse gas than CO_2, seemingly small amounts of leakage can offset any reduction in carbon emissions that occurs from switching to natural gas from petroleum. In addition, significant energy is required to compress the natural gas for distribution through long pipelines.

Despite these caveats, fuel switching does offer considerable potential for carbon reductions in transportation, if energy inputs into production and distribution can be kept to a minimum, and leakage can be reduced by employing existing end use technologies that optimize the fuel to promote complete combustion.

Reaching towards a 10 percent penetration of natural gas into the automobile market is a feasible goal for 2005, as the market gears up to meet a significant increase in demand for such vehicles in California over the next decade.

RENEWABLE ENERGY POTENTIAL. Ethanol as a motor fuel offers significant environmental benefits over fossil fuels, since it is produced from biomass. A number of countries already have considerable experience with ethanol. They include Brazil, the U.S. Mid-west, and other provinces, such as Alberta and Saskatchewan.

Ethanol is an alcohol fuel, and it can be made from corn, wood, or municipal solid wastes. It can be used up to a 10 percent blend as an octane enhancer in gasoline, without any modification of the engine, or as a "neat" fuel on its own, in a modified or dual fuel engine. Other applications also exist which might serve to reduce greenhouse emissions, including use of ethanol, instead of fossil fuels, as a chemical feedstock and production of ethanol from the non-plastic fraction of municipal solid waste, thus reducing methane leakage from landfills. If the ethanol is produced from crops grown on a sustainable basis with a minimum of energy and chemical inputs, its use can reduce CO_2 emissions up to 100 percent, since the CO_2 that is released to the atmosphere would be reabsorbed by the next crop.

The global warming advantages of ethanol may be diminished, however, by the substantial use of energy that could be required to plant, fertilize, cultivate, and harvest crops used as feedstock. This is particularly the case with ethanol made from corn.

However, the production of ethanol from lignocellulose crops, such as wood, crop residues, grass, and municipal solid wastes seems to hold greater promise.[63] These feedstocks are not only available in greater quantity and at less cost than starch feedstocks like corn, the energy required to produce them is negligible.

Ethanol made from lignocellulose, assuming economics are right and land use/environmental impacts can be minimized, could represent a major new industry for Ontario. An Ontario company, logen Corporation, is a world leader in the development of the conversion technology, and it operates a small demonstration plant outside of Ottawa. It is now

ready to scale up the technology and is presently seeking partnerships to finance construction of a larger plant that would produce ethanol and generate electricity from the wood waste from the process.

4.4 Measures to Reduce CO_2 Emissions

The economically achievable measures assumed to reduce CO_2 emissions from transportation are explained in Appendix C. The analysis is limited to measures for passenger cars and public transit. They include the following:

FUEL ECONOMY OF TRANSPORTATION:
- By 2005 average on-road auto stock efficiency improves from 11.4 litres/100 km in 1988 to ....6.7 l/100 km
- In order to achieve the above target a gas guzzler/sipper rebate programme is implemented by 1993 that aims to achieve by 2000 an average measured (as opposed to actual on-road) new car provincial fleet economy of ....6.1 l/100 km
- After 2000 the gas guzzler/sipper rebate programme aims to achieve annual improvement in new car provincial average fuel economy of ....5-6% per annum
- Provincial and Metro policies encourage significant investment and expansion in public transit to achieve by 2005 a modal shift from autos to public transit in GTA of...........................15%

SWITCHING TO NATURAL GAS:
- Policies encourage strong initiative by gas industry and utilities and auto industry to encourage 10 percent of passenger auto stock to be fueled by natural gas ....by 2005

RENEWABLE FUEL:
- Policies aim to encourage use of 10 percent ethanol blend in 100 percent of auto stock (except natural gas and diesel vehicles) by...mid-1990s
- R&D aims to commercialize production of ethanol from lignocellulose so that no net CO_2 emissions occur from its use by 2005

The measures result in a reduction of CO_2 emissions from passenger automobiles of 33 percent from 1988 levels, or 6.3 Mt of CO_2. The cumulative reductions for each of the measures is shown in the following table.

Table 4 (b): Summary of CO_2 Reductions for Passenger Autos

Measure	CO_2 reduction *(Mt)*	% share
Fuel economy	3.9	62%
GTA 15% modal shift[1]	0.7	10%
Natural gas vehicles	0.4	6%
Ethanol blend	1.3	21%
TOTAL	6.3	100%

[1] Net of an increases in CO_2 emissions of .25 Mt from public transit.

4.5 Barriers to Achieving Measures

The primary market barrier to the achievement of greater efficiency in passenger automobile transport are continuing low energy prices. While the public complains about federal

and provincial gasoline taxes, motor fuel prices are not only lower than in most other industrial nations (the notable exception being the U.S.), but in real terms they are no higher than they were 30 years ago. Furthermore, since the average fuel economy of automobiles has improved significantly over the last 15 years, car owners don't have to buy as much fuel. The overall proportion of fuel costs in the operating expense of a car has also declined. It is not surprising that the public is growing more responsive to advertising that promotes high performance and utility vehicles that are less fuel efficient.

The market barriers to natural gas vehicles are related more to the present lack of an adequate gas distribution system for such vehicles, their somewhat more limited operating range, and a small sacrifice in performance. The commercialization of the home refueling appliance and technical advances in storage and carburation, however, should change this picture by the mid-1990s, improving the outlook for natural gas vehicles. Gas utilities, however, remain mostly interested in the fleet market, and regulatory incentives to encourage leasing of home refueling appliances to consumers may be necessary to allow more significant penetration of natural gas vehicles for personal transportation.

No technical barriers exist to the use of ethanol blends, which have been widely used in the U.S. and other countries for many years. Indeed, from the point of view of the consumer, the economics of ethanol appears very favourable. Ethanol in a 10 percent blend as an octane enhancer is worth 47 cents per litre (compared with 22-25 cents a litre wholesale for gasoline at a world price of oil of $18) while large-scale ethanol production costs 37 cents a litre. From an industry point of view, however, the marginal cost of ethanol is greater than the marginal cost of petroleum-based additives, so oil companies oppose ethanol's use because it reduces their profit margins and makes them reliant on non-petroleum feedstock.[64] In other jurisdictions, therefore, governments have had to subsidize the oil companies to get them to accept ethanol.

One important consideration presently is the fact that the U.S. presently can export ethanol into Canada freely, however, there is a U.S. tariff against Canadian ethanol that won't come down for some years under the Free Trade Agreement. The government would have to be careful to regulate in such a way that Canadian production, rather than American imports of ethanol, are encouraged.

4.6 What Ontario Can Do

Ontario should be able to significantly reduce carbon emissions in transportation by adopting measures:

- to improve the fuel economy of motor vehicles registered and used in the province;
- to substitute lower carbon fuels or ethanol for petroleum fuels;
- to intensify the population and job density of the province's urban areas that encourages a significant shift to public transit, bicycling, and walking, and;
- to expand in a significant way public transit and high occupancy vehicle infrastructure in the Greater Toronto Area (GTA) and other urban areas, and to expand existing or to establish new regional rail links between urban centres.

The primary strategies underlying these measures should be to reduce dependence on the automobile, aiming towards stabilization of vehicle kilometres travelled in Ontario's urban areas, and to move eventually towards the wide use of lower polluting alternative fuels in road transport.

IMPROVING VEHICLE FLEET FUEL ECONOMY. Ontario has two options to encourage improvement in the fuel economy of light duty vehicles registered in Ontario. Under the Energy Efficiency Act, Ontario has the authority to set efficiency standards for vehicles sold anywhere

in the province. Alternatively, Ontario could modify its gas guzzler tax programme to provide much stronger incentives for consumers to buy cleaner, more fuel efficient cars and light trucks, by establishing a fuel economy "feebate" programme. Combined with a new initiative to scrap the worst polluting, least fuel efficient vehicles from the road, the two measures could significantly improve the average fuel economy of the province's passenger car stock by 2000.

These ideas come from two California initiatives: DRIVE+ and SCRAP. The DRIVE+ programme (Demand Reductions in Vehicle Emissions Plus improvements in fuel economy) will allow the state to set goals for all new vehicle emissions, including CO_2, and to annually adjust the incentives to achieve these goals. Legislation to establish the programme was enacted by the California legislature in 1990, but it was vetoed by the state's previous governor. The new governor, Pete Wilson, has indicated he will sign a new bill, once the state legislature puts it through.

Applying the concept in Ontario would not be difficult. The Province would offer a sales tax rebate to consumers who buy autos and light-duty trucks that have lower-than-average emissions of CO_2 (other pollutants could be included also). The programme would be paid for by sales tax surcharges levied on purchasers of vehicles that have higher-than-average emissions.[65] The province's administrative costs would be deducted from the surcharges collected.

Calculation of the appropriate rebates and surcharges can initially be based on estimating avoided cost of reducing emissions by other means. Such a calculation, using the study's assumptions for California's vehicle market, when performed on the cars manufactured in Canada, results in market shifts indicated in the accompanying table, assuming the programme were applied all across Canada, not just in Ontario.

Table 1: Effect of DRIVE+ on Autos Manufactured in Canada, 1990

Manufacturer/ Model	No. built Canada	No. sold Canada	No. exports	Total L/100 km	CO2 g/mi	Percent change in sales	Change in sales Canada
Chrysler	25276	517	24159				20
Jeep Premier	11613	517	11096	8.71	390	3.93%	20
Jeep Monaco	13663	0	13063	8.71	390	3.93%	0
Ford	385238	38993	346245				-2763
Tempo	109965	14296	95669	8.11	385	-3.41%	-487
Crown Victoria	120414	6502	113912	11.20	497	-4.85%	-315
Mer. Topaz	40623	10978	29645	8.78	384	-17.18%	-1886
Mer. Grd. Marquis	114236	7217	107019	11.20	489	-1.03%	-74
General Motors	415671	36951	378720				-46
Olds Cutlass Ciera	76721	13191	63530	8.68	403	2.45%	323
Chevrolet Celebrity	20335	1325	19010	8.08	338	0.42%	6
Chevrolet Lumina	216991	14803	202188	10.05	n/a	n/a	0
Buick Regal	101624	7632	93992	8.81	417	-4.91%	-375
SUB-TOTAL	*826181*	*76461*	*749124*				*-2789*
Honda Civic	104582	9726	94856	6.26	294	4.74%	461
Hyundai Sonate	27409	7400	20009	8.78	404	-1.32%	-98
Volvo 740 Series	8081	3303	4778	9.05	399	-5.50%	-182
Toyota Corolla	60793	5654	55139	6.96	297	2.48%	140
Suzuki Swift	46606	4334	42272	5.24	262	13.65%	592
SUB-TOTAL	*247471*	*30417*	*217054*				*914*
TOTAL	*1073656*	*106878*	*966178*				*-1875*

The short run effect of the programme on the fuel economy of new cars sold in Ontario, if the same price elasticities assumed in the California study held up locally, would be to achieve an improvement in the average fuel economy of new cars sold in Ontario of 8.7 l/100 km to about 8.3 l/100 km. A reasonable goal for DRIVE+ would be to recalculate the fees and rebates each year to maintain the same rate of improvement through the next ten years, with the goal of achieving an average fuel economy of new cars sold in Ontario of 6.1 l/100 km by 2000.

The analysis indicates that implementing the programme throughout Canada would lead to a total net loss in sales of 1,875 cars. One car in particular, the Mercury Topaz, carries the brunt of the decline, largely because its emissions of NO_x, HCs, and CO are unusually high (almost 60 percent below the "zero" point); its CO_2 emission rate isn't that bad. If the Topaz had the same emissions rating as its cousin, the Tempo, the decline in Canadian car sales would be only 364 cars.

While the sale of cars made in Canada sold to Canadians would decline about 6 percent, this represents less than one percent of all Canadian manufactured cars. Hence, while sending a strong signal to the manufacturers of cars that the public wants more fuel efficient cars, the impact of DRIVE+ on Ontario's manufacturing industry and jobs would appear to be negligible.

Notwithstanding what Ontario can do through the market to encourage consumers to buy more fuel efficient autos, federal regulation of auto and truck fuel economy in both the U.S. and Canada will be essential over the long-term to improving North American vehicle fuel economies. Ontario's leadership (along with California and other states or provinces that might follow suit), however, can send strong market signals to auto manufacturers that, even in the absence of the federal will to act, spur changes in design and engineering to improve the fuel economy of new models.

In addition to the fuel economy feebate programme, an initiative to scrap old vehicles should be explored on a demonstration basis in cooperation with Ontario's petroleum industries, auto manufacturers, and steel recyclers. Such a programme was recently tried very successfully by Unocal Corporation in California, scrapping 8,376 pre-1971 autos and removing 10.7 million pounds of air pollutants from the Los Angeles basin.[66] The programme cost $700 per car or $5.9 million.

Measurements of carbon monoxide emissions from Ontario vehicles driving along the Don Valley carried out last year by the University of Denver revealed that 10 percent of the automobiles surveyed produced close to 50 percent of the total emissions. Although high polluting cars fell into every age category, old autos tended to be worse offenders.

Analysis of the results of the Unlocal programme tend to confirm the University of Denver tests, which have also been conducted in Los Angeles, Denver, and Chicago. The vehicles scrapped, which averaged 5,500 miles per year, emitted 15 times more pollutants than a comparable fleet of 1990 autos travelling annually an average of 15,000 miles. Ontario should establish a similar demonstration project, to determine the cost effectiveness of scrapping old cars as an emission reduction strategy.

SHIFT TO LOWER CARBON FUELS. Both natural gas and ethanol offer significant advantages over gasoline and diesel as motor fuels, not only because their emissions of key pollutants are lower, but for other reasons. They are also superior from the points of view of health, safety, and Canada's energy security. Viewed strictly from a greenhouse gas point of view, their substitution for gasoline and diesel offers an important opportunity for Ontario to

reduce CO_2 emissions from transportation, as well as strategic opportunities to develop new industries throughout the province.

The province has been active for some years encouraging natural gas, by exempting its sale from provincial tax and investing funds in R & D. A particular focus of this effort has been the development of a natural gas urban bus, which Ontario Bus Industries is now prepared to commercialize.

With respect to natural gas, the province should do more, looking beyond just fleet vehicles to passenger automobiles for applications. The province should adopt a goal of achieving a 10 percent share of natural gas in new light duty vehicles by 2005, a policy framework in which a variety of R&D and market incentives would need to be developed to achieve the goal. High on its priority list should be an R &D programme comparable to its bus effort that seeks to develop: (a) natural gas "monofuel" engines for passenger vehicles that optimize combustion to the characteristics of gas, and (b) catalysts that are able to reduce fugitive methane emissions. An important market that may be underestimated at present is the market for mini-cars that are used for commuting and urban run about. Since such cars would be highly fuel efficient, their range would be adequate given a single tank of natural gas. These efficient and super clean urban cars could help reduce urban pollution, and people would be attracted to their environmental friendliness. Such autos would be aimed at the second car market in urban areas.

With respect to ethanol, the government should carefully review the options for gasoline additives to replace lead and seek a way to encourage ethanol blend, perhaps by allowing a credit in the provincial sales tax for the use of renewable fuels, banning petroleum-based additives as a replacement for lead, or simply gradually mandating the use of ethanol, an approach taken by legislation being considered by the U.S. Congress.[67] For the long term, the government should develop an aggressive programme to commercialize ethanol produced from lignocellulose by 2000. The R&D component would focus on reducing the costs of lignocellulose conversion, and methods for mitigating negative environmental impacts of short-rotation intensive cultivation of woody crops. In addition, the government should form industry and financing partnerships to help Iogen move its technology to the large-scale demonstration stage, by urging Ontario Hydro to fund a cogeneration demonstration plant that would produce electricity and ethanol, such as presently proposed by Iogen.

INTENSIFY LAND USE IN GTA AND OTHER URBAN AREAS. As noted earlier, there is a good correlation between population/job density and energy consumption in transportation. An analysis of GTA data suggests that reductions in transportation related CO_2 emissions per capita might be possible by intensifying of land use not only in Metro, but in some surrounding urban centres such as Hamilton, as well as in other urban areas around the province. (See accompanying graph.)

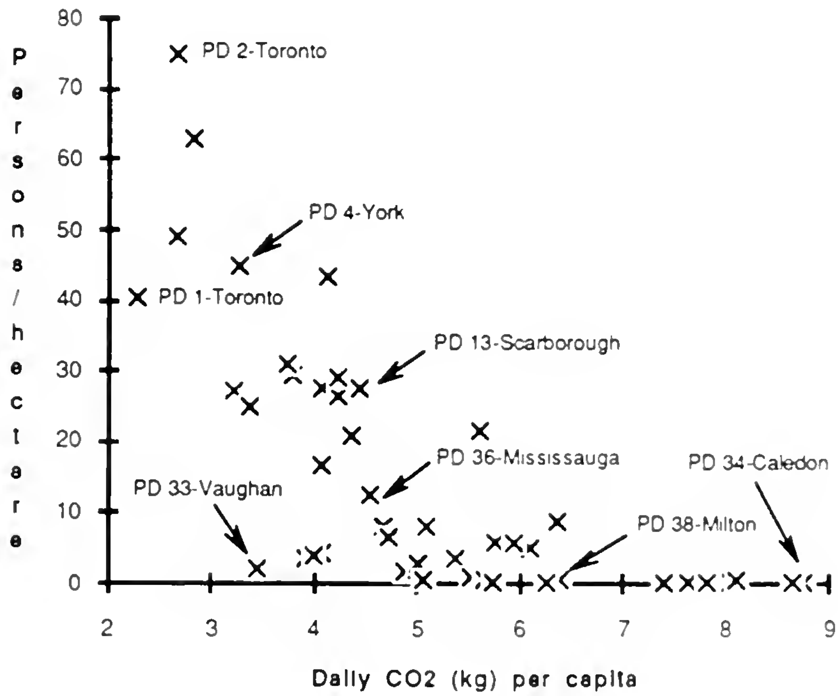
The transportation implications of land use decisions in the GTA have been studied and debated extensively in the past year in an effort sponsored by the Provincial Office of the Greater Toronto Area in the Ministry of Environment. The three concepts for growth in the GTA that have emerged include:

- *Spread*—the status quo, representing the continuation of existing trends that include substantial population growth in low density suburban regions;
- *Nodal*—residential and employment intensification occurring in a compact form around existing communities;
- *Central*—substantial concentration of future growth in Metro.[68]

The "spread" concept would lead to significant growth of radial trips from the regions into Metro, as well as increases in trips among the suburban regions, resulting in a CO_2 increase of 75 percent by 2011. A less extensive freeway network is needed in the "nodal" concept, and a modest extension of rapid transit is assumed, but CO_2 emissions rise 59 percent. In the "central" concept, major extensions of rapid transit are assumed, and only freeway projects already announced are built; in this scenario CO_2 rises 40 percent. Per capita CO_2 emissions fall slightly under the "nodal" concept (one percent), and more under the "central" concept (13 percent).[69]

From an environmental perspective, the debate concerning the three concepts is largely irrelevant, since emissions of all the major pollutants, including CO_2, would increase significantly under every scenario. In addition, large amounts of agricultural land, much of it prime land, would be converted to urban use. The "central" concept is not really as central as it claims, since 200,000 acres of prime farm land would be lost.

Population Density vs. Daily CO2 Emissions for GTA Planning Districts, 1986



With respect to the GTA, the province should rethink the questions and issues of intensification from an environmental perspective. The goal of any long-term plan, in addition to achieving beneficial economic and social changes, should be to reduce emissions of CO_2 and other transportation related air pollutants, to improve air quality, and to minimize impacts on prime farm land surrounding the region.

In order to move in this direction, the province should abandon the present debate about the GTA's future, go back to the drawing boards, and begin a new initiative that seeks to develop an intensification strategy that would reduce dependence on automobiles, reduce transportation energy consumption and related emissions, increase population and job densities in

communities that are already dense, preserve the rural and urban differences that occur throughout the GTA, and significantly expand rapid rail transit.

As a first step, provincial officials should carefully examine policies in other jurisdictions, such as Oregon's urban boundary zone regulations (see Chapter 2) and a newer initiative in Dade County, Florida, for their potential relevance to Ontario. A freeze on all new highway road construction projects, such as the 407, in the GTA, to allow for a new consultation process to address the environmental aspects of land use and road construction would also be appropriate. Planning and construction of roads should shift immediately to high occupancy vehicle (HOV) and bicycle infrastructure.

The new public consultation process should not only address GTA issues, but other major urban centres in Ontario, eventually leading to recommendations for new provincial strategies for:

- intensifying land use;
- protecting prime farm land and preserving rural values;
- preserving and/or restoring natural areas such as remaining wetlands, river valleys, headwater areas, and other significant natural features;
- shifting infrastructure investments from roads to rail and public transit;
- redirecting road supply investments to high occupancy vehicle infrastructure, dedicated commuter bus routes, and bicycle urban bicycle lanes;
- reducing energy in the transportation sector over the long-term.

INVEST IN RAIL TRANSIT, HOV, AND BICYCLE INFRASTRUCTURE. The foregoing discussion of intensification leads to two recommendations addressing the future of the province's transportation infrastructure, the need:

- to significantly expand rail transit in urban areas such as Metro and between important economic centres, such as northern Ontario and southern Ontario, and:
- to strengthen incentives for people to car pool by supporting construction of comprehensive high occupancy vehicle systems and facilities in the GTA and other urban areas.

Urban rapid rail transport is typically more energy efficient than the automobile, and probably is the only way to effectively attract people away from using their cars. Long-distance rail is the least energy intensive way to ship goods, and inter-city passenger rails provides a good alternative to the car for short trips. The province should consider significantly expanding infrastructure investments in both urban and inter-city rail. In the GTA, for instance, the most economical investment would be to use the existing rail corridors for local rapid rail, linking new stations with municipal surface transit and infill residential and commercial developments. The rail corridors are valuable, underutilized public assets waiting for development. Many major attractions and hubs, such as Pearson Airport, the Metro Zoo, and Ontario Place would benefit significantly if they were linked together into a regional rapid rail system.

When the average automobile is fully occupied, it also is an efficient mode of transport. Declining occupancy rates plague most North American cities, however, including Ontario's cities. To reverse this trend the province should invest significant effort and funds in the development of high occupancy vehicle (HOV) infrastructure and programmes. Ontario's most successful initiative, Ottawa's Transitway, a two lane route reserved for buses during rush hour periods, is unfortunately an isolated example of innovative HOV planning. Ontario's cities should follow the example of several American cities, such as San Diego and Seattle, and develop comprehensive HOV systems, not just piecemeal lanes, that are part of an overall urban land use and transportation strategy.

Bicycles can provide an important alternative to both autos and public transit in urban centres, and they do in many countries such as The Netherlands, where significant funds have been invested in bicycle paths, parking facilities, and other amenities. Ontario governments have yet to take them seriously, however. We suggest that the province undertake a major public works initiative to develop such infrastructure in the GTA and other urban centres around the province.

4.7 Economic and Social Implications

Data presented in Section 4.3, Table 4 (a) shows a 40 percent improvement in fuel efficiency is cost effective and will pay back the car owner in three to five years in energy savings at present gasoline prices. Achieving the target, however, would add about $1,000 to the average cost of a new car, which will make it more difficult for some people to own cars. The proposed feebate program, though, will financially assist the purchase of new fuel efficient cars and, combined with the programme to buy and scrap old cars, should help offset much of the additional cost of buying a new car. Consumers will still have the same range of choice of models. Achieving the target does not mean that cars will have to be "downsized"; it simply means that manufacturers won't have much leeway to "upsize" power and performance.

How will a change in consumer behavior affect Ontario's automobile industries? Some of North America's most fuel efficient cars are manufactured in Ontario, including the Suzuki/GM Swift, Toyota Corolla, Honda Civic, and Ford Tempo, which together make up a third of the province's total production. On the other hand, almost half of the cars built in the province are Ford Crown Victoria, Mercury Grand Marquis, and Chevrolet Lumina, which are not fuel efficient. Among the less fuel efficient models, however, only about three percent of the total production was sold and registered in Ontario in 1990, while a much higher percentage of the fuel efficient models were sold and registered here. While implementing a programme like DRIVE+ in Ontario will spur some market shifts, on balance it appears unlikely it would adversely affect the province's auto industry.

In sum, almost all of the large cars build in Ontario are exported to the United States. Therefore, the industry is actually a lot more vulnerable to changes in regulatory policy and consumer demand there. Since more stringent CAFE standards seem likely to be enacted by the U.S. Congress in the next few years—a bill mandating 40 mpg by 2000 was narrowly defeated in the Senate in the fall, 1990—Ontario's auto industry should be positioning itself for a new emphasis on fuel efficiency. The Province's commitment to fuel efficiency, and resulting changes in consumer demand, would send a strong signal to the industry that it is time to prepare for a future that is fast approaching.

The fuel substitution initiative that is likely to have the most economic and social impact is ethanol, and the impacts are likely to be mostly beneficial for Ontario. First, the province will begin producing its own transportation fuel derived from local resources, thereby lessening dependence on external sources of petroleum. Second, should the conversion of lignocellulose to ethanol prove commercially viable by 2000—the cost of conversion has dropped many fold in the last ten years, reaching 23 cents/litre in leading laboratories—production of the fuel should open up new economic opportunities.

A provincial initiative that potentially will have the most impact economically and socially would be a deliberate effort to encourage significant intensification of urban areas. From an infrastructure investment and maintenance point of view, such an initiative is likely to prove the least cost approach to meeting future transportation needs. Building and maintaining public transit systems is less expensive over the long-term than building and maintaining roads.

ENDNOTES

[55]See discussion in Michael Walsh, "Motor Vehicles and Global Warming", *Global Warming: The Greenpeace Report* (1990)

[56]Ibid.

[57]"New Cause of Concern on Global Warming", New York Times, February 12, 1991, p. B9.

[58]Philip Jessup, *Carbon Emissions Reduction Options in Canadian Transportation*, Discussion Paper No. 1, Friends of the Earth, Ottawa (July, 1989)

[59]Marc Ledbetter and Marc Ross, *Supply Curves of Conserved Energy for Automobiles*, University of California, Lawrence Berkeley Laboratory, Berkelely, California (March, 1990)

[60]U.S. Senate, *S. 279, A Bill To Amend the Motor Vehicle Information and Cost Savings Act*, Washington, D.C. (January 29, 1991)

[61]U.S. Department of Transportation, *Effect of Car Size on Fatality and Injury Risk in Single-Vehicle Crashes*, HS 805-729, Washington, D.C. (August 1990)

[62]Peter Newman and Jeffrey Kenworthy, in *Cities and Automobile Dependence: A Sourcebook* , Gower Technical, Sydney, Australia (1989)

[63]Lee R. Lynd, "Large-Scale Fuel Ethanol from Lignocellulose: Potential, Economics, and Research Priorities", *Applied Biochemistry and Biotechnology*, Vol. 24/25, 1990, p. 717.

[64]Techtrol Ltd., *Bio-Energy: A Major Industrial Opportunity*, Montreal (1991)

[65]Deborah Gordon and Leo Levenson, "DRIVE+: A Proposal for California to Use Consumer Fees and Rebates to Reduce New Motor Vehicle Emissions and Fuel Consumption", Lawrence Berkeley Laboratory, Berkeley, California (July 1989)

[66]John Rafuse, "Data and Lessons from Unocal's South Coast Recycled Auto Project", Testimony before the U.S. House of Representatives, Committee on Energy and Commerce, Subcommittee on Energy and Power, October 1, 1990

[67]U.S. House of Representatives, *The Ethanol Motor Fuel Act of 1987*, introduced by Congressman Richard Durbin and Congressman Edward Madigan

[68]Greater Toronto Coordinating Committee, *Greater Toronto Area Urban Structure Concepts Study: Background report No. 1—Description of Urban Structure Concepts*, IBI Group, Toronto (June, 1990)

[69]Greater Toronto Coordinating Committee, *Greater Toronto Area Urban Structure Concepts Study: Background report No. 3—Transportation Systems*, IBI Group, Toronto (June, 1990), Exhibit 33

CHAPTER 5—INDUSTRIAL SECTOR

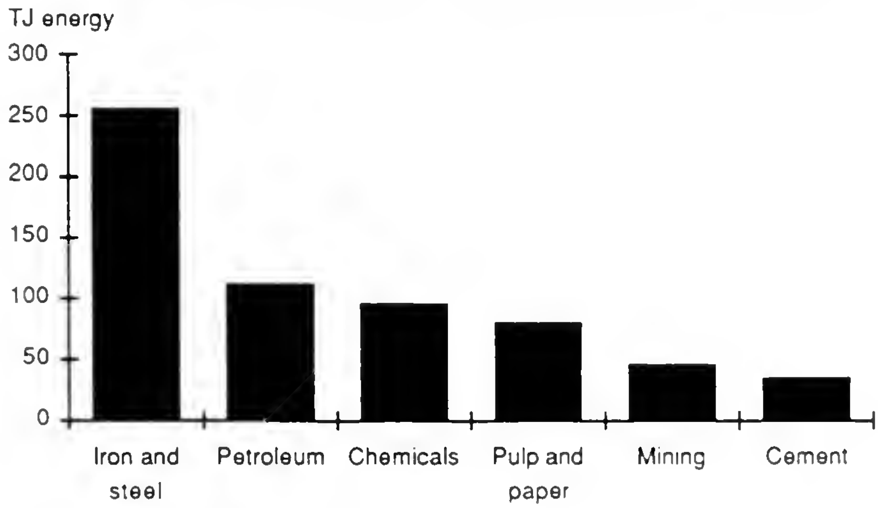
"In terms of initial action, Imperial believes steps that make sense in their own right are most appropriate, such as energy efficiency improvements that can achieve economic returns at least equivalent to the cost of capital. This allows simultaneous progress as uncertainties are reduced in global warming science and socio-economic impacts and as the negotiation of international protocols proceed."

Imperial Oil Ltd., *"Draft Discussion Paper on Global Warming Response Options"* (April 1991)

5.0 Introduction

The industrial sector is the largest consumer of energy in Ontario. In 1988, this sector accounted for 1,318 PJ, about 35 percent of Ontario's total energy. The major industrial energy users are: iron and steel, chemicals, pulp and paper, mining and cement.[70] Together they accounted for approximately 61 percent of total industrial energy in 1988.

Figure 5 (a): Ontario Industrial Energy Use, 1988



Energy use in the industrial sector is unique in two ways. First, it is the only sector in which coal is employed as a significant direct energy source. Second, the energy requirements of industry include very high temperature, large scale, energy intensive processes and equipment, such as blast furnaces and large motors. Other sectors tend to comprise many, small-scale activities, such as heating buildings or operating motor vehicles.

Natural gas is the largest source of secondary energy in the industrial sector, providing 39 percent of the total. Industry is also the largest consumer of natural gas, comprising 45 percent of total natural gas use in the province.

The heavy reliance on coal in the industrial sector—it accounts for 23 percent of secondary energy—is attributed to the iron and steel industry, which requires coal in order to produce coke. Indeed, 31 percent of all coal consumed in Ontario is used to make steel. The cement industry is the next largest industrial consumer of coal in Ontario.

Electricity comprises 20 percent of industrial secondary energy consumption. While both the residential and commercial sectors are more electricity intensive, industry consumes 38 percent of Ontario's electricity, more than the other sectors. The share of electricity has been increasing in industry due to the growth in new electricity-intensive technologies and the increase in electronic and computer-based applications in industry. These structural, procedural and process trends, if they continue, will strengthen demand for industrial electricity, particularly if fossil fuel-based processes such as blast furnaces are replaced by electric arc furnaces in the iron and steel industry.

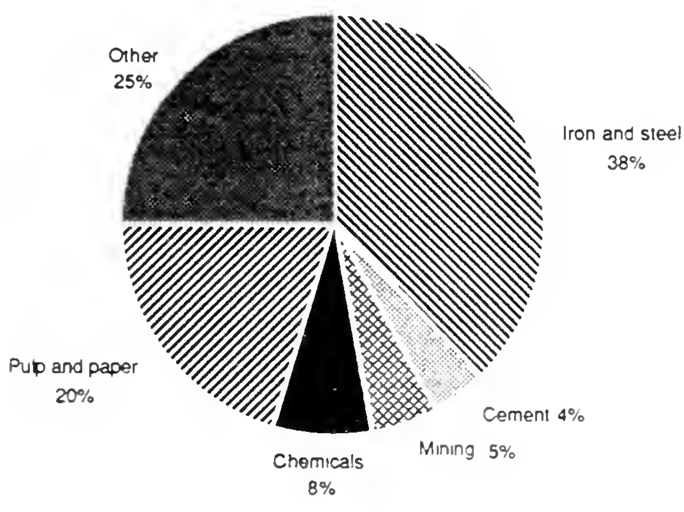
Oil is the source of 11 percent of total secondary energy consumed by industry. Substitution of natural gas for oil has reduced oil consumption in industry over the past two decades. Wood waste and spent pulping liquor are used as an energy source by the pulp and paper manufacturers and now account for over half of that industry's total energy needs.

This chapter provides an overview of energy trends, efficiency potential, and economically attractive CO_2 reduction measures in industry. Given the wide diversity of sub-sectors and industries in each sub-sector, only one industry is examined in depth, the iron and steel industry, as a case study in Chapter 6. It is by far the largest emitter of CO_2, accounting for 40 percent of the sector's total.

5.1 Profile of CO_2 Emissions

In 1988, Ontario's industries emitted 64 megatonnes (Mt) of CO_2, 39 percent of the province's total. The following chart shows approximate direct CO_2 emissions generated by each of the major industrial sub-sectors. After the iron and steel industry, the pulp and paper industry is the second largest producer of CO_2, accounting for 20 percent of the total for this sector.

Figure 5 (b): CO2 Emissions by Industry, 1988



Industrial CO_2 emissions from secondary energy declined between 1980 and 1988. However, when emissions related to electricity generation are included, emissions remained relatively constant over the period.[71]

The industries that contributed most to the reduction in industrial CO_2 emissions from secondary energy were the iron and steel and the petroleum refining industries. Since these industries did not introduce major new technologies during the 1980s, the primary cause for the reduction appears to be a declining level of output due to reduced demand for the products manufactured by these industries. Advances in operating efficiency and other cost-cutting measures introduced in the mid-1980s also contributed to lower energy consumption and reduced CO_2 emissions.

The Ministry of Energy forecasts industrial CO_2 emissions to be 49 percent higher in 2005, more than double the average forecast increase of 21 percent for all sectors combined. Moreover, industry's share of CO_2 emissions is forecast to increase seven percent by the year 2005.

5.2 Profile of Energy Intensity Trends

Energy intensity in the industrial sector in Ontario is high in comparison to almost all other industrial nations, despite the energy efficiency strides that have been made over the past decade. Two major factors contribute to Ontario's high energy intensity: the large proportion of energy intensive primary industries and the availability of relatively inexpensive energy, which discourages efficiency.

Nonetheless, industrial energy intensity (excluding petrochemicals and non-energy uses) fell 34 percent between 1979 and 1985, measured in terms of energy used per dollar output.[72] Two factors contributed to this reduction in energy intensity: direct efforts to reduce energy costs by improving the efficiency of industrial processes; and, more importantly, structural changes in Ontario's economy. Rising energy prices in the early 1980s were a major catalyst for Ontario industries to improve energy efficiency. Efforts to reduce energy costs in industry included the replacement of inefficient equipment, use of new production processes, and fuel switching.

The cement, chemical, and pulp and paper sub-sectors made significant gains, each with a decrease in energy intensity of over 20 percent from 1979 to 1985. The iron and steel industry saw a decrease of six percent over the same period. Pulp and paper remains the most energy intensive industrial activity in Ontario, consuming nearly 30 MJ per dollar of output (in 1984). The iron and steel industry consumes approximately 12 MJ, which is lower than the total industrial average for Ontario.

The effects of structural changes in Ontario's economy are complex, but according to an EMR study, they made a greater contribution—54 percent—to improved industrial energy efficiency than direct efficiency efforts.[73] One fundamental change has been the increased growth in the less energy intensive industrial sub-sectors relative to the energy intensive industrial sub-sectors, such as those referred to in this report. The increase in GDP attributed to light industry has grown substantially over the past decade. This increase is due to changes in consumer demand and a decline in output of certain energy intensive products. Specific sectors, sub-sectors and even processes within sub-sectors need to be compared directly in order to gain accurate insight into the relative efficiency improvements of Ontario's industries. Such analysis, however, is beyond the scope of this report.

Over the long-term, it is safe to say that industrial energy intensity will continue to decrease in Ontario over the next 20 years, as less energy intensive industries and products grow faster relative to heavy industry, and as new production processes and efficient equipment replace aging ones. For example, in the iron and steel industry the trend is towards production of

specialized, high quality steel products, often made in "mini-mills" that require less energy to produce a product unit than the larger blast furnace dominated mills.

5.3 Opportunities for CO_2 Reductions

Approximately two-thirds of energy consumed by industry is used to create process heat, and natural gas is the major fuel for industrial process heat. The remaining third comprises motive power, electrolytic processes, space heating, lighting, and feedstock uses.

A detailed breakdown of these industrial end-uses is difficult to make, since data are not available. A simplified approach attributing the generic end-use categories to fuel type, based on Ontario Hydro analysis, is employed in the industrial sector analysis and is described in Appendix E.

Since a large share of industrial energy is used to create process heat, significant opportunities for improved efficiency and CO_2 reductions exist in the recovery and reuse of steam in production processes. Use of cogeneration to produce heat and power simultaneously and the recycling of waste heat with heat recovery systems are two strategies currently being used by industry on a limited scale. Considerable scope exists for their wider application.

The other area where potential efficiency gains are significant are electricity end uses. The four major end uses are: motive power, electrolysis, process heat, and lighting. Approximately 75 percent of total industrial electricity is used for motive power, which includes motors to operate pumps, fans, compressors, conveyors, and mills for grinding, crushing, rolling, etc.

Opportunities for CO_2 reduction in the industrial sector are described in two ways. First, opportunities which can be applied to generic activities across all industries are presented, and, second, opportunities in specific industries are outlined. Specific opportunities in efficiency, fuel switching and renewable energy are also examined, but in less detail than for the sectors in the previous sections of this report. Information sources, unfortunately, are scarce and tend to be focused on narrow technical opportunities.

GENERIC OPPORTUNITIES. A recent study of energy related greenhouse gas emissions in Canada estimates that a technical potential exists for a 24 percent reduction in CO_2 emissions in the industrial sector between 1988 and 2005.[74] According to the study, the most cost-effective measures for reducing emissions are those that improve energy efficiency, as opposed to fuel substitution. Since the Inter-Fuel Substitution Demand (IFSD) model was used, the projected increase in electricity prices eliminates the cost-effectiveness of fuel switching and specifically, the potential for widespread introduction of cogeneration.

Efficiency measures. According to a recent Ministry of Energy study on electricity conservation in Ontario, energy savings of 17 percent between 1989 and 2000 are possible through electricity conservation measures in the industrial sector.[75] The major areas of savings identified in the study are motive power (variable speed drives), waste heat recovery, lighting, electrolysis, process controls, refrigeration and motors.

House keeping measures also offer substantial opportunity for improving energy conservation. Ministry of Energy reports, independent reports, and industry experts have all pointed to the importance of incremental improvements in general house keeping, which, although difficult to quantify, appear to offer a minimum savings of 10 percent across all forms of energy consumed.

Motive Power. A recent EMR study presents a detailed analysis and recommendations regarding the potential for energy conservation in industrial drive power in Canada.[76] The drive-power savings arrived at in the study are Canada-wide, but, according to the study "the overwhelming majority of installed industrial motor capacity" across Canada is of the same type (AC polyphase induction). Therefore, it is assumed that the results present a fair representation for Ontario. A summary of drive power savings identified for three industrial sub-sectors is presented in Table 5 (a).

TABLE 5 (a): Summary of Drive Power Savings

Industry	Savings *GWh*	Savings *PJ*	Reduction %
Pulp and paper	19,541	70.3	21.3%
Chemicals	3,811	13.7	18.0%
Iron and steel	2,089	7.5	14.9%
TOTAL	25,441	91.5	20%

GWh=million kilowatt-hours; PJ=thousand trillion joules
Source: Industrial Drive-power Case Study, EMR, 1990

The study recommends replacement of aging equipment with high efficiency motors and pumps, and improved matching of motive speed and torque to actual instantaneous loads. The study estimates that motive power efficiency measures adopted by pulp and paper, iron and steel and chemical industries could result in a 20 percent energy savings by 2020. This estimate is likely to be extremely conservative, since the federal Inter-Fuel Substitution and Demand model (IFSD) used to forecast the results projects a real decline in electricity prices over the next 30 years, a forecast that seems quite improbable.

Heat Recovery. A number of opportunities are available for recovering waste heat and reusing it to heat other industrial processes. Heat pumps, heat exchangers and vapour recompressors are three relatively cost-effective methods of recovering waste heat.

Pinch Technology (a computerized process for determining optimum heat recovery and heat pumping according to fuel price) is a recent innovation which can produce fuel savings between 25 and 40 percent. Pinch technology is an analytical technique used to identify specific capital investments in more energy efficient process hardware as well as optimising industrial processes. It is best applied to new plant design. However, it has been used successfully in retrofit situations providing payback in the nine month to three year range. Optimizing heat recovery in industry can result in an estimated reduction in energy consumption of 15 to 20 percent of current levels and improve efficiency in new plants by 40 percent. A conservative estimate of savings in heat energy is 25 percent.

Energy efficient lighting. Lighting comprises approximately eight percent of industrial electricity use. Industrial lighting typically has a higher utilization than commercial lighting, although industrial lighting tends to be more efficient than lighting in other sectors. Savings of 60-65 percent for the industrial sector appear to be economically attractive.

Cogeneration. The simultaneous production of electricity and heat from a single source of energy is called cogeneration. The source of energy is generally natural gas. Cogeneration has four major benefits for Ontario:

- Substantial cost savings can be realized by industries participating in cogeneration;
- Ontario Hydro can benefit from the avoided cost of building new power plants;

- Effective electrical generation efficiency can be doubled, as compared to coal-fired generation;
- Major reductions in CO_2 emissions on the order of two-to-four fold are possible.

Cogeneration has an advantage over conventional thermal generating plants because of its ability to exploit waste heat created in the production of electricity, thereby improving overall cycle efficiency. In addition, electrical transmission losses, approximately 7-to-10 percent, are eliminated since the cogeneration facilities are located at the point where electricity is required. Other advantages of cogeneration include the substantial savings in land use due to the distributed nature of the power production. This is particularly important when considering large nuclear plants or dams situated long distances from end-users, requiring massive land right-of-ways for the transmission lines.

Cogeneration is typically employed by industrial facilities using large steam boilers and steam turbines, or gas turbines with waste heat recovery boilers. Interest in cogeneration has also resulted in the development of smaller cogeneration systems that can be used by light industry or in commercial sector applications. Specific applications of cogeneration in the steel industry are discussed further in the case study for that industry.

A report to the Ministry of Energy has estimated the economic potential of cogeneration in the industrial sector to be 1,942 megawatts (MW), or 42 PJ of electricity, assuming the units operate at 80 percent capacity.[77] The report considers the implementation potential to be somewhat less (1,347 MW). However, changes in fuel and electricity prices since the study was a conducted have improved the economic outlook in favour of more cogeneration. The authors now estimate that the economic potential identified may now be a reasonable implementation potential. With real increases in electricity rates by 2005—and higher buy-back rates offered by Ontario Hydro—it is estimated that an even larger cogeneration potential could be realized by 2005.

Renewable Energy. The use of renewable energy (excluding hydro) is relatively limited in the industrial sector. The increased use of solar energy, biomass, and to a lesser extent, wind power, can provide an environmentally advantageous source of power for industry. Due to the uninterruptable supply and high energy intensities required by large industry, however, it is unlikely that alternative energy sources will play a major role in this sector in the near term. On the other hand, numerous opportunities for passive solar buildings and active solar water heating are present in light industry and should be exploited. These applications resemble those in the commercial sector.

One potential source of significant CO_2 reductions using renewable energy in industry does exist, however, in the pulp and paper industry. The primary source for energy in this sector is wood and wood waste, which accounted for 10 Mt of CO_2 emissions in 1988. If the forests that provide wood feedstock to the industry were managed on a sustainable basis, so that the biomass energy derived from them is all renewed by natural regeneration or silviculture, then such emissions could be reduced 100 percent when measured on a *net* carbon basis. (The same reasoning underlies the proposed shift to ethanol as a transportation fuel, outlined in Chapter 4.)

5.4 Measures to Reduce CO_2 Emissions

The most important measures for reducing CO_2 emissions in the major energy consuming industry sub-sectors are described in this section. Industry specific policies for the iron and steel industry, are discussed in detail in Chapter 6. Estimated savings potential for the major industrial sub-sectors, based on a survey of recent studies, are as follows.

PULP AND PAPER INDUSTRY. The pulp and paper industry is the most energy intensive industry in Ontario, consuming approximately 30 MJ per $1984 of output. It is also the second largest consumer of energy and second largest emitter of CO_2 in Ontario. The pulp and paper industry is, however, unique in that 48 percent of the energy used comes from wood waste or spent pulping liquor. This form of energy comes from recycled waste that would otherwise not be used. The CO_2 emission rate associated with burning wood waste, however, is 100 Kt/MJ of energy, higher than other energy sources.

There is a continuing debate among policymakers whether CO_2 emissions produced from burning wood for energy should be included in provincial and national emissions inventories. The Coalition believes that wood should be included, with the proviso that forestry management practices that seek to ensure replacement of the harvested biomass be allowed to offset such emissions. Hence, the most significant CO_2 reductions role for the pulp and paper lies in the area of changing forest management practices. A more serious commitment to selective harvesting practices (as opposed to clear-cuts) and to silviculture to ensure that all biomass that is harvested is replaced by new growth could enable the pulp and paper industry to offset all of the wood-related CO_2 it emits into the atmosphere by ensuring adequate new biomass growth.

For the purposes of this analysis, it is assumed that some efficiencies can be gained in the motive power component of the pulp and paper industry, some opportunities for cogeneration exist, and that a 10 percent housekeeping reduction can be achieved in the use of burning wood waste.

In addition, the analysis presented in Appendix E estimates that net CO_2 emissions can be reduced or offset by 8 Mt (68 percent) by 2005, assuming that the pulp and paper industry by 2005 succeeds in replacing all harvested biomass with new biomass. It should be noted as a caveat, however, that while the Ministry of Energy includes wood-related CO_2 emissions in its 1988 inventory, it does not credit the industry with any offsets in 1988, even though some silviculture is practiced by both industry and the province. As a result, our estimate of an 8 Mt reduction is somewhat overstated, since the base from which the estimate is made is too high because it does not credit present silvicultural practices.

CEMENT INDUSTRY. In the cement industry, energy costs comprise 40 percent of total production costs. Therefore, programmes to improve energy efficiency should be welcomed by the cement industry, particularly in light of projected electricity price increases. Waste-derived fuel is being explored by at least one major cement producer (St. Lawrence) and will meet 20 percent of heat requirements, contingent upon environmental assessment results.

According to an Ontario Hydro study on the cement industry, a 20 percent improvement in energy efficiency is possible in the cement industry by 2015.[78] This estimate is conservative with respect to CO_2 reductions, since the emphasis of the study is on energy efficiency, not CO_2 reduction, therefore numerous opportunities for encouraging less carbon intensive fuels were not addressed. The most significant opportunity for CO_2 reductions is the substitution of natural gas or waste-derived fuel for coal in pyroprocessing. Unfortunately the high cost of natural gas would be prohibitive, which leaves waste derived fuel as an option. Since substantial amounts of heat and power are required to make cement, it is a potential candidate for steam turbine cogeneration. Opportunities for shared inter-industry energy schemes should be encouraged.

The Ministry of Energy projects a 109 percent increase in non-electricity CO_2 emissions for the cement industry between 1988 and 2005. This forecast anticipates tremendous energy demand growth which appears at odds with recent historic experience. According to the analy-

sis in Appendix E, CO_2 emissions from the cement industry are expected to be 4 percent higher in 2005.

CHEMICALS INDUSTRY. A comprehensive review of energy conservation potential in the chemicals industry in Canada has been completed for Energy, Mines and Resources.[79] According to the study a total energy savings across all fuels and industrial processes in the chemical industry could result in a savings of 37 percent by 2020. Since the focus of the report was energy savings and not specifically CO_2 reductions, it is anticipated that greater reductions in CO_2 emissions would be possible with emphasis placed on the use of less carbon intensive energies in combination with the energy efficiency measures described in the study. Moreover, the EMR study uses IFSD supply price forecasts which project a steady decrease in electricity prices between 1988 and 2020, reducing the potential for switching to natural gas as well as reducing cogeneration opportunities and estimates for CO_2 reduction.

The analysis in Appendix E identifies a 15 percent reduction in CO_2 emissions from the chemicals industry by 2005. This reduction is consistent with the estimates for specific efficiency measures identified in the study referred to above. Improved drive power efficiencies, heat recovery, improved electrolytic processes and overall efficiency improvements achieved with the aid of PINCH technology contribute to the savings in the chemicals industry.

OTHER INDUSTRIES. CO_2 emissions can be reduced seven percent by 2005 in the "other" industries not specifically addressed in this report. This is a reduction of 1.6 Mt and can be attributed to the specific measures summarized in Appendix E.

In summary, a net reduction in CO_2 of 15 percent (9.2 Mt) appears economically attractive in the industrial sector assuming the measures outlined above are implemented. Most of the reduction occurs in the pulp and paper industry as the result of the adoption of renewable forestry management practices. For the rest of industry dependent on conventional fossil fuels, therefore, the case presented here is essentially a scenario to stabilize CO_2 emissions in this sector at 1988 levels by 2005. The following table summarizes the results, which are based on the analysis in Appendix E.

TABLE 5 (b): Summary of CO_2 Savings

INDUSTRY	CO_2 reduction 1988-2005 (Mt)	Change from 1988 (%)
Chemical	0.6	13%
Iron and Steel	(0.6)	(3%)
Cement	(0.1)	(4%)
Pulp and Paper	7.9	67%
Other	1.4	6%
TOTAL	9.3	15%

5.5 Barriers to Achieving Measures

The primary barrier to achievement of efficiency measures in industry is the short payback period that is compelled by the way financial investments are typically assessed by most companies, which is compounded by the low price of energy which industry pays. Given the high rate of return that financial managers typically seek, one-to-two year payback, for instance, is a typical requirement for energy efficiency expenditures. Except for energy intensive industries where the factor cost of energy may affect international competitiveness, therefore, energy use does not usually concern most industries. Indeed, of all the sectors, the industrial

sector in Canada has experienced the least reduction in energy intensity over the past two decades, and more of the reduction in the sector is attributable to structural change than to efficiency improvements.

5.6 What Ontario Can Do

In order to encourage a reduction in industrial CO_2 emissions by 2005, Ontario's government should consider five broad options, some of which are already being pursued, but which could be intensified. They include:

- Encouragement of energy efficiency within all industries, through a variety of strategies, such as: providing information and incentives for general industrial efficiency improvements (eg. high efficiency motors, variable drive motors, lighting etc); encouraging the development and use of more efficient industrial processes (eg. new steel making technologies);
- Creation of regulatory mechanisms, such as a cap on emissions from the largest sources of CO_2, and/or market mechanisms, such as an emissions trading programme, energy taxes, and other approaches to achieve stabilisation of CO_2 emissions at 1988 levels by 2005 in this sector;
- Requirement of higher Ontario Hydro buy-back rates to encourage the full development of cogeneration potential in this sector and the substitution of natural gas for coal and oil;
- Policies to facilitate the restructuring of the industrial sector, placing emphasis on those industries or components of industry which are less energy intensive;
- Greater tax and other incentives for research, development, and commercialization of energy efficiency technology and alternative energy sources in industry.

The following are a number of specific suggestions to implement these broad options.

ENERGY EFFICIENCY ESCOS. Industrial energy efficiency can and should be improved beyond the levels permitted only by short payback periods. Aggressive measures are required to identify areas for improvement and to provide a mechanism to affect change.

One approach would be for the government, in collaboration with labour unions in specific industries that have good labour-management relations and with Ontario Hydro, to encourage the formation of special purpose energy service companies (ESCOs) operated by the unions. The purpose of the labour ESCOs would be to pursue maximum efficiency measures in a particular industry, the result being a revenue flow from the company to the ESCOs based on the energy savings achieved.

Several key ESCOs could be created using the expertise of labour organisations in each industry, Ministry officials, Hydro industrial efficiency experts, and specialized consultants. This joint approach, particularly with the participation of labour, will facilitate the introduction of unique measures at the plant level, while permitting all stakeholders with an opportunity to "buy in" to the process.

The ESCO would fund capital improvements to plants through a combination of labour union pension funds and Hydro avoided cost funds targeted for conservation. It is recommended that a demonstration ESCO be created for a small industry where energy savings can be demonstrated and industrial relations would presently permit such cooperation.

ESCOs would focus on all of the generic industrial opportunities and house keeping improvements, as well as certain industry specific opportunities appropriate to the expertise of the ESCO.

REGULATORY CONTROLS AND MARKET APPROACHES. Controlling CO_2 emissions through regulation will form an important part of a carbon reduction strategy for Ontario. Two options are described below. The preferred option is a cap on CO_2 emissions from the majority of large point sources of CO_2 in the province, coupled with an emissions trading programme to allow industries to find the least cost control option.

One option for reducing industrial CO_2 is to use the existing regulatory framework for control of air pollution. The framework for most air pollutants is the Environmental Protection Act and Regulation 308, the General Air Pollution Regulation. The Act requires a certificate of approval for all sources of air contaminants and the Regulation specifies the standards for individual contaminants that all sources in Ontario must meet. These standards are expressed as concentrations at the "point of impingement", the highest concentration at a receptor downwind of a point of emission.

CO_2 is not now regulated through this mechanism, and Regulation 308 is not considered to be an effective option for reducing CO_2. This is due to the nature and limitations of the point of impingement standards, particularly as they relate to the specific characteristics of CO_2. First, the concern with CO_2 is not with the effect on a particular receptor, but with the gradual increase in total CO_2 levels in the atmosphere. Point of impingement (POI) standards do not provide this measurement. Second, POI standards accommodate dilution and dispersion of stack gases. These standards may improve local air quality for individual contaminants, but do not affect total loadings of CO_2. Third, POI standards do not establish a cap on total loadings of contaminants into the environment. In order to achieve reductions in CO_2 emissions, total loadings must be specified.

Regulation 308, however, is now undergoing change, and POI may not be a mainstay of the programme in the future. There may be new capability to provide a regulatory mechanism for a cap and, if so, this framework should perhaps be revisited for the purpose of controlling industrial CO_2 emissions.

A second option using existing regulatory authority could be to establish a cap on emissions of CO_2 from the largest industrial emitters and allocate allowable emissions among them. This quota type system could be based on the approach taken to control acid gas emissions in Ontario. In the Countdown Acid Rain programme, the Ministry of the Environment focused on the four largest emitters of sulphur dioxide (Inco, Falconbridge, Algoma and Ontario Hydro). Using individual regulations for each emitter, total annual loadings were established for 1994 and a timetable of interim reductions was set out. The companies were required to research and develop the means for meeting the 1994 limits. All four have successfully developed their own programmes for complying with the regulations well within the schedule.

Ontario's acid gas control programme is a useful model because there are many parallels between CO_2 emissions and acid gas emissions in the industrial sector. There are an identifiable number of larger industrial emitters of CO_2, particularly the iron and steel, pulp and paper, chemical, mining, and cement sectors. Targeting only the major contributors to the problem would facilitate administration of such a regulation. In addition, controlling CO_2 will require the adoption of alternative fuels or process changes that are within the knowledge of each sector. This approach puts the onus on those with the most understanding of the process to find solutions. Most importantly, controlling the effects of greenhouse gases requires setting a ceiling on the total allowable loadings to the atmosphere, which could be more easily done using this approach than the framework in Regulation 308.

A further option with the quota system, allocating emissions among a limited number of polluters, could be to allow emissions trading among those industries. Emissions trading is not

now practiced in Canada, but has been used in the United States since 1976. In principle, emissions trading allows companies to reduce their emissions below their quota and to either use these reductions to increase emissions from another process or facility or to trade the reductions with other companies. This system gives companies a great deal of flexibility in meeting the regulations.

There is concern with emissions trading that, while overall air quality will not be adversely affected, local air quality can deteriorate significantly as the result of a company buying another's quota. The concern with CO_2 is with total loadings, however, so emissions trading may be an effective way of injecting flexibility into the system. There are, however, a number of administrative impediments to an effective emissions trading scheme that would have to be addressed. For example, some view trading of emissions quotas as a "license to pollute", in the sense that the quota is static and companies can pollute up that limit. (The same is true for regulated emissions levels.) This could be addressed for CO_2 by gradually reducing the emissions ceiling over time. Other concerns are the quality of the data among industries, the difficulty of enforcement for regulators, and the difficulty of calculating each company's credits.

A third option could be to regulate CO_2 through the new regime for controlling air pollution in Ontario, known as the "Clean Air Program" or CAP. Reform was first proposed in 1983, and the Ministry of the Environment has been developing the new programme since then. A draft regulation, CAP would change air standards from point of impingement to point of emission, eliminating dispersion as a tool of air quality protection, and would set standards on the basis of the toxicity of the individual contaminant. Three or four levels of concern will be established for classifying air contaminants. For example, the most persistent toxic substances would require the most stringent type of control, known as "lowest achievable emission rate."

CAP as now expressed in the draft regulation does not contemplate regulation of CO_2, but instead focuses on contaminants that are toxic in the sense of their direct impact on human or environmental health. CO_2 could be included as a contaminant, but the present system for classifying contaminates into different levels of concern would have to be modified. The effect of including CO_2 here would be to require every source in Ontario to comply with the new regulation, which may prove administratively difficult.

Perhaps a more effective way of addressing CO_2 within the reforms to the existing regulatory regime would be to focus on a limited number of priority pollutants, including CO_2, and regulate the largest emitters of these pollutants so that all emissions would be minimized. This "shopping basket" approach would ensure that steps taken to minimize one pollutant will not result in an increase in another. However, while this approach has been suggested to the Ministry of the Environment though the public consultation on CAP it is not now part of the draft regulation. We urge its reconsideration.

FUEL SWITCHING STRATEGIES. Fuel switching and cogeneration strategies could reduce emissions in the industrial sector. Industrial sector cogeneration includes both the small commercial size units, for light industry, as well as very large (>50MW) units. The larger units are unique since they are designed to produce more electricity than is required by the "host" plant, so that the excess can be sold back to Hydro. Buy-back rates from Hydro are critical to the economic success of large cogeneration sites. Therefore, buy-back (and actual purchase) rates must be increased to reflect the full external cost of producing electricity, thereby stimulating industrial cogeneration.

In some cases, even more direct collaboration between Ontario Hydro and/or municipal utilities to structure and finance cogeneration projects that increase electricity supply while making a contribution to the modernization of existing industrial capacity may be appropriate.

IMPROVED INDUSTRIAL PROCESSES. The province, in collaboration with Ontario Hydro, should make industrial modernization grants that encourage industries to accelerate the adoption of new industrial processes that offer important energy savings. Other policies such as industrial competitiveness incentives should be explored, including accelerating the amortization of capital intensive equipment used to improve energy efficiency.

Existing programmes which provide grants for industrial demonstration projects and new technologies need to be coordinated across all relevant ministries to provide a more focused industrial strategy for accomplishing energy efficiency and environmental goals. (See Chapter 7.)

In the case of at least one company regulated under the province's acid gas control program, Inco, government industrial modernization funds were provided that permitted installation of new processes that not only reduced sulphur from the ore, but turned the facility into a showcase of new technology that the company is now selling worldwide. There is no reason a similar approach couldn't be used in the province's proposed regulatory initiative to cap CO_2 emissions from major industries.

RESEARCH, DEVELOPMENT, AND COMMERCIALIZATION. Canadian energy use and efficiency is directly affected by both the level and focus of research. Canadian government RD&D budgets for energy systems analysis in 1989 were US$5.3 million, a 75 percent decrease from 1983 and only one percent of the U.S. budget for R & D.[80] Moreover, the majority of Canadian public sector research spending funds mega-energy projects and nuclear power. The research funding emphasis must be directed away from new, expensive and environmentally hazardous energy supplies, toward conservation, and efficiency.

Statistics Canada estimates that only one percent of all annual capital investment in Canadian industry is spent to reduce energy costs. Results of a survey analyzing capital spending patterns between 1985 and 1987 show 53 percent spent to increase capacity, 40 percent for equipment replacement and modernization, one percent for pollution control, one percent for improvement in working conditions and four percent for other reasons.

The goal for improving energy efficiency is therefore to ensure that the 40 percent spending on modernization and 53 percent on expansion includes energy efficiency as one of the considerations in these components of spending, since it is unlikely that the one percent direct spending would have a significant impact on overall energy efficiency.

The Ministry of Energy currently provides several programmes covering development (EnerSearch Program) and demonstration (Industrial Process Equipment Program) of new technologies as well as improving efficiency on-site (Industrial Energy Services Program) and encouraging cogeneration (Cogeneration Encouragement Program).

However, the lack of funds allocated for the commercialization of proven technology is a common complaint regarding government incentive programmes. The establishment of a special fund that aims to commercialize new energy efficiency technologies may provide the boost required by small firms to bring their technology to the market place. A programme of this nature should provide small seed capital grants as well as commercialization and marketing expertise.

INDUSTRIAL RESTRUCTURING. A comprehensive industrial strategy is required to ensure a coordinated and long-term approach to job creation and economic stability, in light of the structural changes taking place in Ontario's industries. New and less energy intensive industries must be provided with opportunities to start-up and grow. Ontario's traditional resource-based economy must be provided with more Ontario-based secondary manufacturing to help

balance the energy intensiveness of the industrial sector, and more importantly, create jobs in the secondary and tertiary sectors. Specific industry sub-sectors need to be identified where Ontario has a comparative advantage and the potential for international leadership. One can argue that Ontario is losing its comparative advantage in the resource intensive primary industries. Our true comparative advantage lies in our well-educated labour force and socially and environmentally progressive society. Industries producing environmental and energy efficiency products should be provided with incentives such as, seed capital, investment tax credits, prime rate loans and other conventional incentives.

5.7 Economic and Social Implications

If nothing is done to reduce costs and improve the productivity of Ontario's industries, the economic and social implications will be serious. It is critical for Ontario to maintain, or in many instances regain, its international competitiveness, in order to reverse the trend of jobs being lost to other countries. The prospect of a permanent loss of labour-intensive manufacturing in Ontario is high. According to some economists there will never be a full economic recovery, following the current recession, in all sectors as long as Ontario's competitive position remains so poor. Adopting aggressive measures to improve energy efficiency will provide one means for cost reduction in Ontario's industries, as well as creating an opportunity to once again provide technological leadership in growing fields (environment and energy) and an opportunity for people to move into better jobs.

The recommended measures depend on the flexibility of specific industries affected and the ability of Ontario industries to act upon the opportunities created through energy efficiency measures.

ENDNOTES

[70]Ontario Ministry of Energy (November 1990)
[71]Ontario Ministry of Energy, *Ontario's Energy Related Carbon Dioxide Emissions*, Toronto (1990)
[72]Ontario Ministry of Energy, *Industry Energy Trends*, Toronto (1986)
[73]EMR, Energy Demand in Canada, 1973-1987: A Retrospective Analysis, Ottawa (March 1989)
[74]DPA Group, Inc, *Study on the Reduction of Energy Related Greenhouse Gas Emissions*, Toronto (1989)
[75]Ontario Ministry of Energy, *Electricity Conservation and Acid Rain in Ontario*, Toronto (1989)
[76]EMR, *Remaining Energy Conservation Potential in Canada: Industrial Drive-power Case Study*, Ottawa (November 1990)
[77]Acres International, *Cogeneration Potential in Ontario*, Toronto (February 1987)
[78]Ontario Hydro, *An INDEPTH Model of the Ontario Cement Industry*, Toronto (1990)
[79]EMR, *Industrial Sector Case Study—Chemical Industry*, Ottawa (1990)
[80]CIPEC, *Canadian Industry Program for Energy Conservation* (October 1990)

"In the high-value enterprise, profits derive not from scale and volume but from continuous discovery of new linkages between solutions and needs....Steelmaking is becoming a service business, for example. When a new alloy is molded to a specific weight and tolerance, services account for a significant part of the value of the resulting product. Steel service centers help customers choose the steels and alloys they need, and then inspect, slit, coat, store, and deliver the materials."

Robert B. Reich, from *The Work of Nations* (1991)

6.0 Introduction

The iron and steel industry in Ontario employs over 60,000 people. This number is declining, as are the net incomes and outputs of Ontario's major integrated steel manufacturers. The major integrated steel makers (those which typically own coal and iron mines, produce coke, and manufacture steel) include only two major companies in Ontario, Dofasco and Stelco. There are numerous smaller steel companies in Ontario which play an increasingly important role in steel production. Costeel (Lasco) is one notable mini-mill with a reputation for quality steel and advanced technology. The top producers and employers in Ontario are listed in Table 7 (a), following.

TABLE 7 (a): Top Steel Producers In Ontario (1989)

Name	Revenue ($million)	Employees
1. Dofasco	3,908	22,700
2. Stelco	2,749	16,147
3. Ivaco	2,086	11,500
4. Canron	483	2,532
TOTAL	9,226	52,879

Source: Financial Post 500, 1990.

The steel industry in Ontario has reached a critical point. Iron and steel demand is low, competition from cheaper producers is increasing, technological changes are happening rapidly, permitting more efficient production, and environmental and cost concerns are forcing the steel industry to adopt more efficient measures.

At the end of 1988, U.S. steel makers supplied 2.5 percent of Canadian demand. By the end of 1990, their market share had increased to 17 percent. Major economic restructuring of this nature has severe social and economic implications for Ontario. The economic downturn which began in 1989 and is expected to continue for another year, has eroded demand for structural steel, rails and other industrial products. The future does not look very encouraging for the Ontario steel industry, which is operating at less than 50 percent capacity. Dofasco's Algoma subsidiary is barely solvent and job losses may be as high as 25 percent of the total work force in three to five years.[81] In ten years, Stelco's work force has been reduced 81 percent, from 26,000 employees in 1981 to 14,348 employees in 1990. According to steel analysts, this figure could drop to as few as 9,000 by 1991.

The auto industry and petroleum industry comprise the major markets for Ontario's steel, in the form of flat-rolled and tubular steel. Lower car sales, or more importantly the lower ratio of domestic to foreign sales, combined with low oil prices (and therefore a lack of exploration) have contributed to major losses at Dofasco, Stelco and Algoma last year. Work stoppages at Stelco and Algoma added to the losses and contributed to the increase in U.S. imports.

Historically, Ontario's steel industry has been very profitable and highly regarded internationally. The combination of readily available and inexpensive raw materials (iron ore and coal) with captive and somewhat protected local markets (auto and oil exploration) provided the Ontario steel makers with a significant comparative advantage over many other nations. Consequently, there was little incentive for the Canadian steel industry to pursue the aggressive cost-cutting and energy cutting programmes that other countries, notably Britain and Germany, have had to undertake.

Consequently, in a matter of a few years, Canada has lost its comparative advantage to countries who have invested in major cost-reducing programmemes. Cost reductions are therefore essential if the Canadian steel industry is to survive.

6.1 Rationale for Profiling the Steel Industry

Ideally, each of the major industrial sub-sectors should be examined in detail in order to identify specific opportunities where energy efficiency can be introduced and CO_2 emissions reduced. Such a research effort, however, was beyond the scope of this project. Nonetheless, the iron and steel industry in Ontario has been selected for more detailed examination, for several reasons.

- it is the largest industrial producer of CO_2 in Ontario;
- it is the largest industrial consumer of energy in Ontario;
- there is Canadian ownership, therefore, Canadian accountability;
- there are significant opportunities for efficiency improvements;
- major research activities on energy efficient technologies are currently in progress world wide;
- major implications for the Canadian steel industry may result from the U.S. Clean Air Act coke oven regulations;
- Ontario Hydro's INDEPTH Model of the Ontario Iron and Steel Industry provides a comprehensive analysis of current steel making processes and new technologies.

Finally and perhaps most importantly, the iron and steel industry in Ontario is in the midst of troubled times, providing an excellent opportunity to examine measures for improving it's efficiency and competitiveness that could be compatible with an effort to reduce CO_2 emissions.

6.2 Profile of Energy Use

Ontario's iron and steel industry is the largest single energy consuming industry in the province. Over 253 PJ of secondary energy was consumed by the iron and steel industry in Ontario in 1988. Coke and coke oven gas make up approximately two-thirds of the total energy requirements. Electricity accounts for nine percent of the total energy consumed in producing iron and steel. This makes the iron and steel industry the third largest electricity consumer in the province after pulp and paper and chemicals.

Figure 4 provides energy used by the steel industry for each energy source as a percentage of total industrial energy use for the given sources. Over 80 percent of the coal used by

industry is used to make steel. Less than 20 percent of the three remaining major sources of industrial energy; natural gas, petroleum and electricity, are used in the steel industry.

Coal is the major energy source in the steel industry and is an essential component of integrated steel making. Coal is burned in coke ovens, to produce coke, which is essentially pure carbon. Coke is needed to fuel the blast furnaces as well as to "reduce" the iron. Reduction is the chemical reaction between the carbon in coke and the oxygen in the molten iron, which removes the oxygen, by producing CO_2 and carbon monoxide.

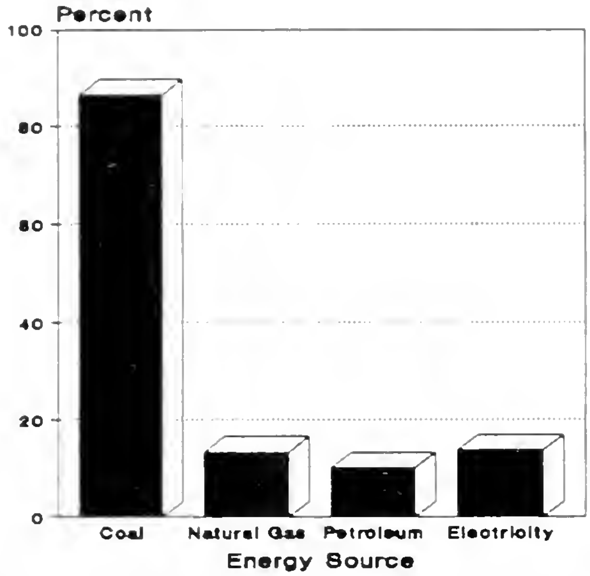


FIGURE 4 STEEL INDUSTRY ENERGY USE AS A PERCENT OF TOTAL INDUSTRY

Electricity is used by both the integrated mills and the mini mills. In the mini mills, unlike integrated mills, electricity is the primary source of energy and electricity intensity in mini mills is nearly double that of the integrated mills. Mini mills melt scrap metal in electric arc furnaces (EAF) and therefore consume far less energy per tonne of steel.

Although EAF steel making is preferable to coke-based steel, the massive electricity consumption of an EAF carries with it the problems of low primary energy efficiency, transmission losses, and potential CO_2 emissions from coal-fired electricity generation. As the technology in mini mills improves, EAF will continue to encroach on the markets of the integrated steel makers.

Mini mills have the added environmental advantage in the role they play as recyclers of scrap metal. At Lasco, Canada's largest mini mill, approximately 900,000 tonnes of scrap metal are recycled annually.

Figure 5 illustrates the increasing role EAF made steel is playing in Canadian steel production. In 1989, 31 percent of Canada's steel was made in electric arc furnaces, up from 13 percent in 1970.

6.3 *Profile of CO_2 Emissions*

The iron and steel industry had direct CO_2 emissions of 18.4 Mt in 1988. Accounting for indirect CO_2 emissions from electricity use, approximately 15 percent of all CO_2 emitted in Ontario can be attributed to making iron and steel.

As described above, CO_2 is produced in the iron making process in several ways. However, four-fifths of the CO_2 is produced by burning coke in the blast furnace. Nearly nine percent of all CO_2 emissions in Ontario can therefore be attributed to one process in one industry—coke for steel making.

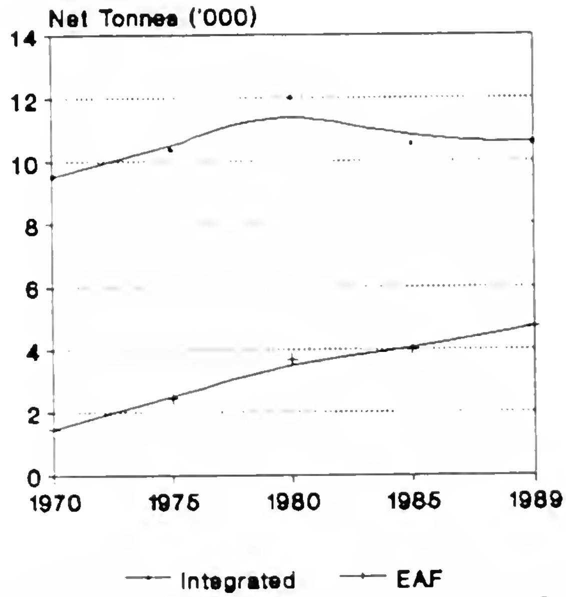


FIGURE 5 INTEGRATED MILL VS. EAF STEEL PRODUCTION

Other direct and indirect CO_2 emissions from steel making, although small in comparison to coke-related emissions, still represent a significant overall source. Electricity is used for EAFs, electric ladle preheating and motive power. Natural gas and oil are not widely used in steel making, although a new process (Midrex, described below) uses natural gas and electricity instead of coal.

6.4 *Opportunities for CO_2 Reduction*

Substantial research is underway worldwide to reduce the energy intensity, and more specifically the need for coke, in the steel making process. There are two fundamental methods to pursue in achieving this goal. First, is through meticulous "housekeeping" measures. Second is the introduction of new steel making technologies, described below.

Housekeeping measures include; regular maintenance and cleaning of equipment, particularly coke ovens, recycling flue gas and other waste heat, furnace insulation and sealing, micro-processor controlled reheat furnaces, fuel substitution, recuperative burners, byproduct recovery, increased use of scrap metal and general efficiency consciousness.

Many of the generic industry policy recommendations described above can be applied to the steel industry, particularly regarding motive power efficiency and heat recovery. It is important to note that Canadian steel makers have invested substantially in research and new technologies to reduce costs, limit emissions and improve energy efficiency. These achievements are discussed following the discussion on new technologies.

It is the opinion of leading steel industry research experts that the incremental, relatively low cost improvements have far more potential in the near term for reducing energy consumption and CO_2 emissions than the introduction of major capital intensive technologies. This would appear to be particularly applicable in Ontario, where additional major capital expenditures would be inconceivable given the financial position of Ontario's steel industry. Nonetheless, significant attention is being given to new steel making technologies and the research being undertaken by the steel industry to develop cokeless steel making.

NEW TECHNOLOGIES. The alternative technologies being explored fall under three basic categories; direct reduction, direct smelting, and direct steel making. Direct reduction iron (DRI) is a process where iron ore is reduced without melting the iron and also eliminates the need for coke ovens and blast furnaces.

A number of commercial DRI plants are operating throughout the world, including Quebec's Sidbec-Dosco plant. Sidbec uses the Midrex process, considered to be the best DRI process. Midrex uses a large amount of natural gas to reduce iron pellets in a shaft furnace. Coal-based direct reduction processes are also in use, but less successfully.

Direct smelting processes eliminate the need for coke ovens and blast furnaces. The Corex (or KR) process appears to be one of the more promising direct smelting technologies being tested.

An ISCOR steel plant in South Africa is the first full-scale steel facility demonstrating Corex technology. The Corex process (as with other direct smelting processes) eliminates the need for coke ovens and blast furnaces. Coal is used directly with iron pellets to melt and reduce the iron. Early operating performance at the ISCOR plant (following a brief shutdown) is encouraging, which may provide the impetus required for other steel-makers to build commercial Corex plants.[82] Weirton Steel in West Virginia came close to building a Corex plant in 1987, but the plans were shelved due to more pressing capital commitments. Plasmamelt and ELRED are two other direct smelting processes. The former uses plasma for melting the steel, therefore requiring a large amount of electricity and the ELRED process uses a DC arc current and a combined-cycle cogeneration plant. Although considerable research energy is being expended on all three processes, the steel industry does not appear to be embracing the technology.

Direct steel making is the most advanced steel making technology being explored and involves burning coal instead of coke, similar to Corex. The American Iron and Steel Institute (AISI) is leading a $30 million study in direct steel making. Assuming the development of commercial processes, it is predicted that direct steel making could cut U.S. coke demand by 98 to 99 percent by the year 2030.[83] Japanese steel makers are also working on a direct steel making project budgeted at $90 million. According to the publication <u>Iron Age</u>, reduced coke demand attributed to direct steel making would not likely exceed 7.8 percent by the year 2000. Others are less optimistic.

In addition to the new technologies being developed for efficient front-end steel making processes are the advances in hot steel output processes. Traditionally, steel was first made into ingots, which had to be cooled, then reheated, then rolled flat, trimmed and sometimes reheated a second time. This process is very inefficient. Continuous casting and thin slab casting are

two advances in steel finishing which eliminate cooling-reheating steps as well as reduce waste steel.

Continuous casting comprised 77 percent of Canadian steel production in 1989. In 1970 less than 12 percent of Canadian steel was continuous cast. Thin slab casting is a more recent advance in steel processing which will most likely follow the success rate of continuous casting. Nucor Inc., the tenth largest steel maker in the U.S., is the first company to make commercial use of thin slab casting. Although numerous difficulties were encountered in bringing the process on stream, analysts predict that large steel makers will adopt the process since it offers substantial savings in energy, time, and resources.

CANADIAN RESEARCH AND DEVELOPMENT. Both Dofasco and Stelco have excellent reputations internationally for research and innovation. However, the focus of research has been primarily on quality control and steel finishing, as opposed to cost reduction and energy efficiency. This follows logically from the relative position of security and profitability these companies had throughout the 1970s and mid-1980s.

Six of Canada's major steel producers (including Stelco and Dofasco) are partners in a research endeavour called Project Bessemer Inc. The partners are committed to spending $20 million over seven years to do research on thin-slab continuous casting.

THERMAL COGENERATION AND OFFGAS RECOVERY. The use of cogenerated thermal energy can result in considerable energy and cost savings (10 to 20 percent) for the metals industry.[84] High temperature exhaust gases from combined cycle turbine generators can be used to preheat scrap, ladles, furnaces, fuel, and additives.

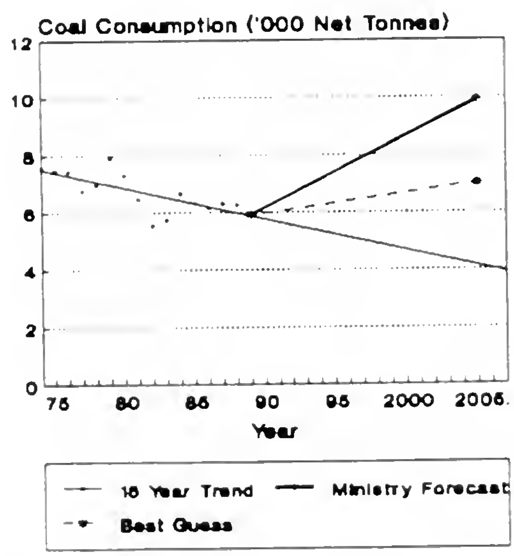


FIGURE 6 COAL CONSUMPTION TREND COMPARISON

Furnace offgas recovery is a similar concept whereby the high temperature gases released from steel furnaces (either EAF or traditional blast furnaces) are used to preheat scrap before entering the furnace. The Consteel (continuous steel) method for EAFs makes use of energy that would otherwise be wasted, as well as offsetting the amount of electricity required to

melt the scrap metal. In addition to energy and cost savings, offgas recovery to preheat scrap provides for better working conditions by reducing noise levels fumes and dust emissions. Furthermore, the system is reported to have a return on investment of approximately one year.[85] One Ontario company (EMPCO Ltd. of Oshawa) markets a Consteel scrap preheating system in Canada.

REDUCED DEMAND. Figure 6 illustrates the actual 15 year trend of coal consumption in the steel industry in Canada, projected ahead to 2005, versus the Ministry of Energy forecast for Ontario coal consumption in 2005. The third line (Best Guess), is the authors' best estimate based on discussions with steel industry representatives, the general economic outlook and conditions in the Ontario steel industry. The lines serve to demonstrate that the Ministry of Energy projection for coke related CO_2 emissions in 2005 appears to be high, particularly in light of the fact that coal consumption has been decreasing in the steel industry for the past 15 years. Moreover, economic predictions for Ontario's steel industry suggest that a turnaround will take several years and full recovery may never occur. If this is the case, CO_2 reductions in the steel industry may reach 20 percent by 2005 based on reduced steel output, product specialization and increasing proportion of EAF steel. The "best guess" scenario estimates that coal consumption in the steel industry will increase 20 percent from 1989 levels. Steel tonnage output will increase at a slower rate than dollar value output as the industry shifts to higher quality, value-added specialty steel products. Future steel demand will be met increasingly by the mini mills, which do not cause any increase in coal consumption.

6.5 Barriers to the Introduction of Efficiency Improvements

Numerous reasons are frequently cited for Canadian industry's reluctance to innovate. Among the reasons are: inability to fund major capital expenditures, unwillingness to wait for long payback periods, lack of confidence in unproven technologies, difficulty moving away from the status quo, and the general risk adverse nature of Canadians. None of these reasons appear to be the case in the iron and steel. As described above, the Ontario steel producers have invested heavily in modernization and innovation. They have had to in order to remain competitive.

There do not appear to have been any specific "barriers" to introducing energy efficient technologies. A more practical explanation is that management priorities have been focused on different aspects of technological innovation. The priority for the Ontario steel industry has been product quality, and therefore a focus on steel processing technologies such as the Bessemer Project, rather than technologies to replace coke and blast furnaces. Moreover, coke ovens in Canada are considered to be more efficient and less polluting than many of the U.S. coke ovens.

Improvements in efficiency and productivity in traditional steel making also act as a barrier to adopting new technologies. According to the President of USX Corp., one of the largest steel makers in the U.S., technologies to replace blast furnaces often lag behind blast furnace improvements.

In order to assist the introduction of energy efficient technologies, every effort must be made to ensure that the cost savings component is a significant part of the new technology. The steel industry is highly competitive and virtually all innovation is tied strictly to improving competitiveness through either lower costs or higher quality products. Energy efficient technologies that provide marginal cost benefits and risk disrupting operations will not be accepted by the industry.

The major barrier to producing more steel from electric arc furnaces is the present supply of recyclable steel. The mini mills are also constrained by environmental regulations pre-

venting them from disposing of "automobile fluff" (the non-steel remainders of a shredded car) on-site. Increased understanding of the positive role of mini mills and flexibility in disposal methods would assist mini mills. Fear of an impending energy crisis is also a concern for the mini mills due to their high electricity requirements. Other barriers include an unstable supply (and unstable price) for scrap metal, and the lower quality of steel produced from scrap, making the steel unsuitable for many high finish applications, such as the auto industry.

6.6 Review of U.S. Clean Air Act Provisions for Coke Ovens

Some of the most stringent legislation regarding coke oven emissions is contained in the U.S. Clean Air Act, which became law in November, 1990.[86] Coke ovens are given strong emphasis in the legislation and have unique status regarding certain regulations. It should be noted that the major concern regarding coke oven emissions in the U.S. is benzene (a carcinogen) and that CO_2 is not classified as a toxin under the Clean Air Act.

Two sets of standards are included in the Act, either of which can be selected by the coke producer. Under the first option, existing coke ovens must comply with the Maximum Achievable Control Technology (MACT) emissions standards by the end of 1995, and with residual risk standards by January 1, 2003.

The MACT standards for coke ovens must be at least as stringent as specified limits, such as no more than 8 percent of oven doors leaking. In addition, certain work practice requirements must be met in 1993.

Under the second option, coke ovens have until 2020 to meet residual risk standards. To qualify for this option, coke ovens must comply with the specified MACT limits in November 1993, and with the lowest emission rate achievable by a rebuilt or replacement coke oven. Furthermore, they must meet an even stricter standard by 2020 if EPA finds that control technology has advanced. Coke ovens under option two can be reconstructed and still have until 2020 to meet the requirements.

The U.S. Department of Energy and Environmental Protection Agency are to conduct a six year study to assess coke oven emission control technologies and assist in the development of control technologies. The agencies can provide up to 50 percent of the cost of projects to develop, install and operate coke production emission control technologies. The Act authorizes $5 million annually for fiscal years 1992 through 1997.

6.7 An Integrated Approach to Best Available Technology

In order to make steel as energy efficiently and cost effectively as currently possible, steel makers must take advantage of all of the best available technologies. It appears that the Ontario steel industry is a long way away from replacing coke ovens and blast furnaces. Therefore, in order to achieve the maximum savings possible at least-cost, an integrated combination of best available energy efficiency and fuel switching technologies is required.

For example, an ideal scenario could include a mini mill using a high efficiency electric arc furnace, offgas heat recovery to reheat the scrap metal used to make the steel, maximum practical levels of insulation, continuous thin slab casting, variable drive motors (where required), high maintenance standards, a baseload displacement gas cogenerator used for basic plant electricity needs and space and water heating, high efficiency lighting, and continued research, development, and innovation.

Integrated approaches are required among industries, as well as within industries. The Lasco steel plant has a neighbouring paper company and cement company. Without knowing

the details, it appears that these three plants may be able to take advantage of their different energy requirements in a coordinated approach to energy planning. A natural gas cogeneration unit could provide the electricity for the EAF steel plant and the heat required by the paper plant, while excesses of both could be used by the cement plant. Perhaps the cement plant could also make use of Lasco's "auto fluff" in an energy from waste plant. If industries were provided with incentives to locate adjacent to integrated steel mills or other large industries (specialized business park), excess waste heat could be provided to a district heating system or directly to the plants. Identifying opportunities of this nature would be a useful role for the Ministry of Energy. Significant energy savings may be possible by exploiting these kinds of situations, however, quantifying the potential is very difficult.

6.8 Policies and Measures for Ontario's Steel Industry

Achieving a 20 percent reduction in CO_2 emissions in Ontario's iron and steel industry will require cooperation among industry, government, and labour. Moreover, a comprehensive industrial strategy is required for Ontario to coordinate economic, environmental and energy-related concerns in the steel industry.

There are many energy programmes currently available to industry (cited above) which provide valuable assistance in identifying energy efficiency opportunities and reducing energy costs for industry. In order to achieve a CO_2 reduction of 20 percent by 2005, a much more proactive and aggressive approach to energy savings is required.

The policy recommendations put forward in this document are intended to complement and augment existing programmes, hence the need for a comprehensive strategy and coordination among the Ministries of Energy and Environment, Ontario Hydro, labour and industry.

Iron and steel industry policies can be categorized in a similar fashion to the industry policies described above. Essentially, there are three basic measures to reducing CO_2 emissions in the iron and steel industry; improving energy efficiency, adopting new technologies and capitalizing on industrial restructuring.

ENERGY EFFICIENCY. General housekeeping improvements across all components of the industry, particularly maintenance standards for coke ovens and blast furnaces, should provide measurable reductions in CO_2 emissions.

- Placing minimum industrial efficiency standards in the Energy Efficiency Act for generic industry equipment (drives, motors, fans, lighting, refrigeration etc.)
- Bringing in current best practices for housekeeping will result in an estimated improvement in energy efficiency of 10 percent. Specific measures include: maintenance standards, insulation, efficient lighting, recycling, heat recovery, etc.)
- Maintenance standards and guidelines for regular maintenance and repair of coke ovens and blast furnaces may result in a CO_2 reduction of up to 10 percent.
- Switching to off-peak electricity from either peak electricity or fossil fuels would improve efficiency and reduce emissions.
- The creation of a steel industry Energy Services Company, with joint participation of Hydro, the Ministry of Energy, the United Steel Workers and the steel companies, could identify the housekeeping opportunities and evaluate the energy savings potential in steel plants.

Improving the energy efficiency and CO_2 emissions of current steel making processes is perhaps the best method for reducing CO_2 emissions in integrated steel making.

- The most significant and readily available mechanism for reducing CO_2 emissions is substituting coal for coke in the blast furnace. Coal injection (as it is known) combined with oxygen injection can reduce the coke used by up to 30 percent. Therefore a CO_2 reduction of 5 percent is conceivable through coal injection.
- Ontario hydro funding a portion of the capital cost of new energy efficient devices, calculated according to Hydro's avoidance of cost for supplying increased demand.
- Energy efficiency awareness programmes. Effective communication of the potential for energy efficiency in industry is critical to the successful achievement the Ministry's goals. A simple sustained education programme for industry should be established. The programme could take the form of current Ministry initiatives such as advertising in industrial journals or providing information to be posted in industrial facilities. This can be a low cost means of increasing penetration of efficiency measures.

NEW STEEL MAKING TECHNOLOGIES. It is unlikely that any of the new steel making technologies will be adopted by any steel makers in Canada in the near term, due to the massive capital costs involved and given the substantial sunk costs in current technologies. A strategy for the long term success of Ontario's steel industry should be pursued by the province. One component of such a strategy must be investment in research, development and demonstration of leading edge direct steel making technologies.

- Opportunities for investment in new steel making technology with Ontario Hydro acting as a partner along with private sector capital. Perhaps through the establishment of a venture capital fund.
- Increased funding of joint industrial - scientific research and development.

STRUCTURAL CHANGES IN THE STEEL INDUSTRY. The percentage of steel made from electric arc furnaces increased 143 percent from 1970 to 1988 and comprises approximately 30 percent of Canada's total steel production (approximately 17 percent of Ontario's). EAF steel production is expected to comprise 25 percent of Ontario's total steel production by the end of the 1990s. The production of EAF steel is limited to the demand for the types of products EAF steel manufacturers make. Finite amounts of scrap metal and the lower quality of EAF steel further limit the total production of EAF steel.

Since EAF steel making requires large amounts of electricity, it contributes to CO_2 emissions, particularly if incremental electricity generation is fossil fuel-based. However, the trend toward increasing the percentage of EAF-based steel is important for reducing CO_2, since coke-based CO_2 emissions are many times higher per tonne of integrated steel. Steel from scrap is a laudable environmental objective since it encourages recycling.

Incentives are required to facilitate the proportion of steel produced from scrap, particularly in mini mills employing electric arc furnaces. Incentives to maximize the recycling of scrap metal should be developed, such as refundable deposits on car purchases. Metropolitan Toronto has announced that effective July 1, 1991, no scrap metal will be permitted in its disposal facilities, and the Ministry of the Environment is contemplating provincial bans on recyclable materials at all waste disposal sites in Ontario.

6.9 Savings Summary

In order to reduce CO_2 20 percent of 1988 levels by 2005 the total CO_2 for the steel industry would have to be reduced to 202 PJ (or 16027 Kt CO_2) in 2005, a nearly 50 percent reduction of forecasted 2005 levels. One of the principal components of CO_2 reduction is revised energy consumption forecasts (Table 3) based on the following assumptions.

MEASURE	% IMPROVEMENT
General housekeeping	10% of all energy
Coal injection	5% of coal-based CO_2
Motive power	20% improvement in motive power
Heat recovery	25% improvement in all non-coal heat
Cogeneration*	35% savings in utility electricity
Lighting savings	65% improvement in lighting

* Cogeneration is addressed in the electricity section and not included in the industrial analysis.

The scenario for reducing CO_2 emissions in the steel industry results in a net increase in CO_2 emissions of three percent in 2005, according to the projections used in Tables 1a through 1g in Appendix D. Although far from meeting the objective of a 20 percent reduction, the results demonstrate a significant difference in point of view from the Ministry's projected 56 percent increase in CO_2 in 2005. The major factors contributing to the savings include the lower growth rate in coal consumption and more aggressive efficiency measures.

6.10 Economic and Social Implications

In many of Ontario's energy intensive industries, significant cost cutting will be required to maintain international competitiveness in the face of free trade. Since energy costs are a major factor in these industries, investments in energy efficiency and cogeneration technologies should lower factor costs and improve the prospects for these industries over the long-term. In one industry, the pulp and paper industry, the implications of implementing sustainable harvesting and silvicultural practices to reduce net CO_2 emissions from the use of wood waste for energy needs more careful examination, however. This particular industry in undergoing significant change due to the shift to paper recycling in the U.S. (and Canada) and other competitive pressures, and it is not known how sustainable forestry practices would affect the industry's bottom-line.

ENDNOTES

[81]*Survival of Steel*, Hamilton Spectator (April 6, 1991)
[82]George McManus, *Corex Comes Onstream*, Iron Age (March 1990)
[83]George Hess, *Iron-makers Clean Up Operations*, Iron Age (August 1990)
[84]Ronald Carson, *Thermal Cogeneration for the Metals Industry*, Iron and Steel Engineer (September 1990)
[85]George Hess, *Scrap Preheating Fuels Energy Savings*, Iron Age (December 1990)
[86]Environmental and Energy Study Institute, *EESC Summary of Laws: 1990 Clean Air Act Amendments*, Washington, D.C. (1991)

CHAPTER 7—A GLOBAL WARMING INDUSTRIAL STRATEGY

> "The conflict between environmental protection and economic competitiveness is a false dichotomy based on a narrow view of the sources of prosperity and a static view of competition. Strict environmental regulations do not inevitably hinder competitive advantage against foreign rivals; indeed, they often enhance it. Tough standards trigger innovation and upgrading."
> Michael Porter, from The Competitive Advantage of Nations *(1990)*

7.0 Introduction

A major effort over the next 15 years to reduce the energy intensity of the province's economy and to reduce CO_2 emissions will create important new opportunities for technological and economic advancement. The implementation of the initiatives put forward in this report for each of the sectors could well generate a wide array of new economic opportunities for Ontario, ranging from the production of efficient residential appliances or the components for new energy efficient commercial lighting fixtures to the development of leading edge alternative energy technologies accompanied by related manufacturing.

Each of these potential opportunities will have to be assessed independently to determine its economic viability and to determine what support, if any, the province should give to capitalize on the opportunity. The diverse nature of the R&D, manufacturing and distribution activities that could be associated with a global warming strategy will make it difficult for the province to implement a single initiative to ensure such activities are based in Ontario. Furthermore, many of the issues related to Ontario's competitive position with respect to these activities are in fact just a microcosm of the larger issues of technological capability and competitive manufacturing capabilities that go well beyond the scope of this project.

This case study examines one area of advanced technology—natural gas cogeneration—that is likely to create important opportunities for the Ontario economy, should the province deem an important role for parallel generation in reducing future CO_2 emissions. In particular, the opportunities for smaller institutional and commercial installations are explored, not only because they could be developed in the relatively near term if buy-back rates are higher, but because they have generally been overlooked by Ontario Hydro's Non-Utility Generation Plan, which foresees a maximum of only 85 MW of potential over the next 25 years.[87] A transportation application is also explored.

Two technologies—diesel engine cogeneration (adapted for natural gas) and fuel cells— are explored to demonstrate the kinds of economic benefits that could result from a commitment by the province to the development and application of a particular technology which would contribute to the reduction of CO_2 emissions. They are not necessarily the technologies that the government might choose to pursue. The initiatives proposed to support the commercialization and market application of these two technologies, however, would apply to other technologies as well, as well as assist the government in its pursuit of environmental and energy related goals.

7.1 Diesel Cogenerators and Fuel Cells

Diesel/natural gas cogeneration and fuel cells in the 100-500 kW capacity range were selected for a number of reasons. The primary ones are: significant technical potential that exists for cogeneration in Ontario's residential and commercial sectors, a total of 5,400 MW according to a recent study, and the significant contribution they would make towards reducing

CO_2 emissions—if their technical potential can be partly achieved—by eventually displacing central coal fired power. [88]

Diesel/natural gas cogenerators for building installations could represent a broadly based economic opportunity, for several reasons.

- They potentially have wide application in both the residential and commercial sectors;
- They are commercially available and have been proven in many applications in other countries;
- They are already accepted by industry, and some of their component parts can presently be manufactured in Ontario; final assembly can occur in Ontario as well;
- They enjoy efficiencies in the 70-80 percent range;
- At least one Ontario company, Atlas Polar, is already gearing up production of a 250 kW system, and Ontario Hydro has expressed interest.

While the potential economic and environmental benefits from natural gas fuel cells are more long-term, there are several reasons why they should receive the attention of utility planners and policymakers, despite the high cost of the first generation of commercial systems.

- They have significant commercial potential in the future because they are modular, low polluting, and quiet in operation and thus can be scaled to any size and sited almost anywhere, including urban centres;
- They have efficiencies in the 80-to-90 percent range, and unlike most combustion turbines and diesel engines, they maintain their efficiency over varying loads;
- The potential for reduction in manufacturing costs is substantial, once economies of scale can be reached;
- Commercial production has already begun in Connecticut of one system;
- The thermal/electrical ratio is more evenly balanced than in combustion technologies, allowing for higher capacity utilization;
- Current investment requirements for testing and commercialization could create an opportunity for Ontario to get in on the ground floor with this technology, and Japanese, American, and European consortia have formed to exploit fuel cell development and are looking for partners;
- A Canadian company in British Columbia, Ballard, has already developed the leading fuel cell contender for transportation applications.

The Province should be taking steps to take advantage of the economic opportunities that are likely to arise in the next one-to-three years from the application of these technologies. Encouraging and/or participating in investments in the development and commercialization of technologies could contribute to longer term environmental objectives, as well as significant competitive advantages in economic terms.

7.2 The Role of the Entrepreneurial Company

Although the focus of this case study is on natural gas technologies, smaller entrepreneurial companies have been selected—Atlas Polar and Ballard—rather than the utilities, primarily because small businesses in recent years have been the engine of Ontario's economic and job growth. Natural gas utilities provide the conduit for the distribution of natural gas, and their primary function is to link customers to their gas distribution networks rather than to sell them the gas that flows through the pipes.

(While theoretically there is no incentive for a gas utility to "sell" gas, since their revenues are generated through the hook-up and furnace and water heater financing, in reality, however, vertical ownership in the industry, most notably British Gas' stake in both

Consumers Gas (the utility) and Bow Valley Resources (the gas producer) precludes impartiality to sales. This situation is important to note when considering efficiency and conservation incentives.)

While the utilities themselves are clearly involved in new product development, and in some cases, in the financing of smaller technology firms—British Gas committed to establish a venture capital fund for such investments as part of its purchase of Consumers Gas—much of the new commercial activity in this field is likely to come from smaller entrepreneurial companies. As in most industrialized companies, these smaller, growth-oriented firms are playing an increasingly important role in the development and commercialization of new technology-based products and services in Canada. However, many Canadian technology firms have been tripped up by their inability to market effectively or their lack of management skills, with the net result that many such companies have failed to realize the potential they were thought to have.

As society's awareness around environmental issues continues to grow, and governments respond with progressive environmental initiatives, large new markets will be created for a wide variety of goods and services related to the environment. Government policy must be mindful of the need to support Canadian and Ontario-based firms in their efforts to capture these markets.

The research for this phase of the project has reinforced the perception that smaller entrepreneurial firms are likely to be actively involved in the development and application of technologies intended to help protect our environment. The two leading firms in Canada in the fields of natural gas cogeneration for smaller installations and natural gas fuel cells are Atlas Polar and Ballard Technologies.

7.3 Atlas Polar

As has been made clear in previous sections of this report, there is significant potential for cogeneration in Ontario. The issues limiting its use are economic and political rather than technical at this point.

The opportunities for cogeneration in Ontario can be divided into two categories. The first includes smaller scale installations (up to 2 MW), which are guided by the fundamental principles of cogeneration efficiency (requiring roughly equal outputs of heat and power) and are designed primarily for load displacement. The second type of cogeneration opportunity involves larger installations which are driven primarily by the economics of independent power production. An investment in cogeneration for private power production must be able to generate significant revenues from the sale of excess electricity, regardless of the heat requirements. Since it is more difficult to sell heat than power, the trend in large scale cogenerators is therefore towards electricity plants with minor (perhaps 10 percent of total) heat production.

One of the main differences between the small proprietary cogeneration plants and the larger third party operated industrial plants is the relationship between the cost and the price of the electricity and the heat. In the case of the smaller proprietary plant, the energy consumer is receiving heat and power at "cost". The economic incentive is therefore to produce heat and power at a lower cost than the cost for which it can be purchased.

In a third party cogeneration plant, the operator of the plant is selling the heat and the power to the host customer as well as to other customers. Therefore, the incentive is to produce power that can be sold at a lower price than that charged by other sources. This implies that the heat and power must be produced at a lower cost in a third party operation if it is to generate an acceptable profit margin.

The principle impediment to the increased use of cogeneration in Ontario, particularly for larger third party plants, is the low price that Ontario Hydro currently pays to buy back excess electricity. For the large cogeneration facilities, the price that Ontario Hydro is willing to pay is an important factor, since this revenue is one of the major reasons for getting into private power production in the first place. The buy-back rate for large independent producers is somewhat lower than Ontario Hydro's full cost of avoiding investment in a new nuclear plant.

For smaller cogeneration facilities, the issue is more one of capital cost than buy-back rates, since these producers are typically more interested in meeting their own needs than in selling electricity. Most prospective candidates for a small cogeneration facility would be looking for a payback period of less than five years before considering a capital investment of this nature.

Atlas Polar is an Ontario-based company already active in smaller cogeneration installations. The power engine division of Atlas Polar has been investing in the design and development (with financial support from Ontario Hydro and the Ontario government) of a 250 kW cogeneration system which is now installed in nine of the 10 sites in Ontario where cogeneration units of this size can be used for load displacement purposes. The company maintains that the current economics allow for a payback period of four-to-five years on a system of this size, which is short enough to start to make cogeneration an attractive economic option. Once that has been established, the market for these smaller cogeneration units should start to grow rapidly, and the company estimates a market potential of about 500 MW for the 250 kW system.

This load displacement market encompasses mostly institutional and commercial facilities. A constraining factor at this point is the amount of thermal (heat) energy these facilities require. In many instances, the only thermal requirement is for heating the building, and minor requirements for water heating. In the absence of a need for a roughly equivalent amount of heat, the economics of cogeneration evaporate quickly. However, it appears that gas absorption chilling is now considered to be a viable option for meeting the air conditioning requirements of a building, which means the thermal output from the cogeneration unit can be used year round, strengthening the economics of the unit.

Atlas Polar believes that there will be considerable market potential for their load displacement cogeneration units within the next decade, up to 500 MW for its 250 kW system. The economics of the unit are now favourable enough for much of that market potential to be achieved, according to the company.[89] The issue for Atlas Polar now is how to capitalize on that potential.

7.4 Ballard Technologies

Fuel cells can be divided into five types, based on the nature of the underlying technology: phosphoric acid (PA), molten carbonate (MC), solid oxide (SO), alkaline (A), and solid polymer (SP). Each of these technologies has its strengths and weaknesses, which in turn create different opportunities for commercial application.

The PA fuel cell technology is perhaps the best established and has been the focus of considerable research in Japan and in the United States. In June of 1990, United Technologies Corporation and Toshiba announced that a subsidiary of their jointly owned International Fuel Cell Corporation would start commercial production of packaged, stationary PA fuel cell power plants of up to 1000 kW capacities for on-site electricity and heat energy services. The cost of these fuel cells is currently about $2500/kW but is expected to fall to the $1000-$1500 range.

Osaka Gas Co. of Japan, is also formally committed to the development and use of the PA fuel cell to enhance their efficiency and control the impact of power production on the environment.

Asea Brown Bovari, M-C Power and the Institute of Gas Technology have announced that they will jointly develop and market MC fuel cells in the United States for a broad range of power generation markets. These MC plants will range in size from about 500 kW for commercial and light industry applications to hundreds of megawatts for central power stations.

Canada has developed some leadership in the solid polymer fuel cell technology through Vancouver-based Ballard Technologies. The SP fuel cell technology has several distinctive features which could lead to two very large commercial applications in the future:

- It runs at 80° C, the lowest temperature of all of the fuel cells, and can be started up almost instantaneously, which gives it potential in the automobile and bus markets; and
- its power density is much greater than that of other fuel cells, which means the fuel cell is much smaller, and could therefore have significant applications at the low end of the cogeneration market.

Commercialization of the solid polymer fuel cell is still some years off, but Ballard has attracted the interest and resources of a number of international investors, including British Gas, which is a positive indicator of its potential. It recently received a $1 million grant from the federal government to facilitate development and demonstration of a hydrogen bus. There are only four or five companies in the world working on SP fuel cell technology, and Ontario should be taking steps to ensure it benefits from the commercial potential of this technology, should Ballard succeed.

There are significant economic opportunities surrounding the application and use of all of the fuel cell technologies, including the storage and distribution of hydrogen, and a variety of integration issues, such as the adoption of the technology to bus and automobile drive systems and bodies. These are areas where Ontario presently has an industrial base. For instance, Ontario already specializes in some areas of hydrogen technology; Electrolizer Corporation of Mississauga, for example, owns 40 percent of the world's electrolysing capacity. And Ontario Bus Industries and other companies have been leaders in the development of natural gas vehicles.

However, the province's ability to potentially capture the economic benefits associated with the development and application of fuel cell technology is limited at present. Just as the "revolution" in information technology and personal computers seemed a long way off in the late 1970s, so too does fuel cell technology at the present time, so few bureaucrats have taken an interest, apart from a modest pilot demonstration of the Ballard fuel cell at Dow Chemical, who manufactures the polymer, sponsored by the Ministry of Energy. However, everyone knows the magnitude of the economic spinoffs associated with the introduction of personal computers across a broad array of industries, and the same breadth of opportunities may well be created by the fuel cell over the next decade.

Ontario is not particularly well positioned at this time to take advantage of these opportunities.

7.5 Capitalizing on the Opportunity: Access to Capital

Like most smaller Canadian companies that have developed some technology with which they have started to open the door on a new market, Atlas Polar now faces the challenge of capitalizing on the opportunity while continuing to invest in the development of new modules for the load displacement market. In short, the company will need considerable resources

so that it can aggressively market the product it already has (the 250 kW unit) *and* continue to invest in the development of the product. Atlas Polar believes that the Ontario market alone for their cogeneration units will be very large in 3 to 5 years time, before one even starts to consider the potential of a national or international market. However, this potential is still unproven, which makes it difficult to borrow the money required for market penetration and continued new product development. These activities should properly be funded with equity capital, but unfortunately, such capital can be difficult to come by for companies like Atlas Polar.

Companies needing equity capital to finance new product development or a growth strategy based on expansion or acquisition, often turn to the venture capital market for this capital. In the case of very small firms, or new companies whose capital requirements are still small (up to perhaps $150,000) the "informal" venture capital market is often the right place to turn. High net worth individuals, particularly those that have made their money through the creation of a successful business, are often interested in investing in other young companies which appear to have growth potential. The informal nature of this market makes it difficult to document the amount of such activity that takes place, but we do know that the informal venture capital market is an important source of equity capital for many young firms during their early days.

However, as its capital requirements grow, a firm must turn to sources that are more likely to able and willing to provide the larger amounts of equity capital required to aggressively pursue their growth opportunities. While venture capital is a $3.5 billion industry in Canada and is a well established part of the capital markets, it has not proven to be a reliable source of capital for smaller technology oriented firms. At present, there are perhaps four Canadian venture capital groups that might consider an investment in a company like Atlas Polar, even though the "technology" content of the cogeneration unit is limited primarily to design engineering. Even though Atlas Polar is an established company, (which clearly reduces the risk relative to a brand new venture) and has already committed its own resources to the development of a product for this segment of the cogeneration market, it would undoubtedly have a difficult time securing equity capital from outside sources to pursue its potential in this market.

The situation facing companies that are actually involved in the development of new technologies whose commercial applications are still at some distance in the future, is even more acute. Ballard technologies is almost conspicuous for its success in attracting a considerable amount of venture capital from international sources when its commercial potential is likely still five years off. It is difficult to find many Canadian companies that have been successful in this regard.

The issues associated with the availability of venture capital for technology-oriented Canadian companies are complex, and a full discussion of them goes well beyond the scope of this report. However, Ontario's ability to capitalize on the economic opportunities created by policies to address environmental issues is bound to be constrained by these issues. In essence, the problem has three parts:

- a limited supply of experienced technology entrepreneurs able to manage and grow a business;
- a limited supply of venture capital investors who understand the technologies and are able to really assist and support a technology oriented companies; and
- a limited supply of capital available for these investments.

Much of the discussion about impediments facing technology oriented companies in Canada has focussed on capital, primarily because that is the easiest of the three issues to pin down. But the people issues are just as important and perhaps even more limiting, and they are

much more difficult to address. Making more capital available for young Ontario firms developing and commercializing environmentally related technologies will not, in itself, solve the problem.

Ontario has a clear commitment to making at least a base level of capital available to these firms. The Environmental Technologies Program, (launched by the Ministry of Environment in March 1990 with a five-year $30 million commitment) is designed to stimulate the development of innovative new products or processes that will protect the environment. Similarly, the Ministry of Energy has $3 million a year available through its EnerSearch program to fund R&D activities focussed on the next tier of commercial energy efficiency technologies. Innovation Ontario, the province's venture capital fund, invests up to $250,000 in equity in Ontario technology firms, although there has been little investment activity to date in environmentally related technology companies.

While there is a legitimate role for the government in providing financial support to encourage innovative young firms to engage in pre-commercial development activity, the same argument cannot, in our view, be made once a product or process is at the commercial stage. Ontario, along with the other provinces and the federal government, have become more active in the early stage technology venture capital market because private sector investors have chosen to leave this market. Rather than attempting to step in to fill the resulting gap, the government should take steps (on both the capital and human resources fronts) to draw them back. In so doing, the government would get better leverage from its own investment, and would be significantly improving the odds of Ontario-based firms participating in and capitalizing on the economic opportunities that are already being created in response to growing pressures to protect the environment.

7.6 Specific Initiatives For Consideration

There are a number of initiatives that the province could undertake to encourage investment in the development and commercialization of technologies that can contribute to the reduction of CO_2 emissions. Such initiatives should be able to support the exploitation of near term opportunities (like expanded use of natural gas cogeneration in the marketplace) and the development of new technologies and applications that will give us a competitive advantage in the longer term (like the fuel cell technology).

Policy initiatives that will support Ontario-based technology companies engaged in the development and delivery of products and services related to the environment are likely to be equally relevant to technology firms involved in other sectors. While the proposals set out below go well beyond the specific goal of capturing the economic opportunities that will be created by a policy to reduce carbon emissions, they are, nevertheless, appropriated and relevant. A strategy to foster the growth and success of technology firms serving diverse markets goes beyond the mandate of any one ministry or agency, and therefore becomes the responsibility of all. The measures proposed below could play an important role in assisting Ontario-based firms to take a leading position in the development and commercialization of the technology based products and services for markets created by growing international concern for the environment.

1. Establish a strategic procurement programme to support the market penetration of environmental-related technologies produced by local firms.

A strategic procurement policy, if properly executed, can play an important role in helping young technology-based companies commercialize their products and increase their market penetration. Government procurement policy can, therefore, be instrumental in support of Ontario-based companies which have developed innovative technologies in response to envi-

ronmental concerns to enter the market on a commercial basis and thereby establish a longer term competitive position in the market. However, care must be taken to ensure that strategic support that seeks to help such companies aims to expand their presence in the market, rather than providing the sole reason for the company entering the market in the first place.

In the case of many technology oriented firms, the expanded production associated with growing demand for their product serves to reduce the unit cost of production, allowing for a lower price to the end-user which in turn further stimulated demand and allows the company to achieve the critical mass necessary to compete in the marketplace. The inability to achieve this critical mass is often a major hurdle to smaller innovative firms establishing a strong position in the market. By pursuing a strategic procurement policy with respect to relevant environmental technologies, the government could stimulate demand to the point where it could favourably influence the economics of production.

The situation facing Polar Atlas is a good case in point. Although the company believes it has established itself in a leading position with respect to small scale natural gas cogeneration units, the size of its market (and hence the use of small scale cogeneration units) is constrained by the cost of each unit. Increased demand for these units could help to reduce the unit cost and improve the economics of installing these system in smaller commercial and institutional settings. The provincial government, as the owner and proprietor of many buildings, could through its strategic procurement policies help expand the use of cogeneration units in the institutional market and, thereby, improve the economics of manufacturing the units in Ontario.

2. Encourage the formation of new pools of venture capital to invest in early stage technology companies.

To retain Canadian capital for technology investing, it is critical that an experienced management pool is in place in both the technology companies and the venture capital funds. However, specific measures are required to stop the flight of capital from the technology sector that has been taking place in recent years, and to convince private sector sources of capital that investing in Canadian technology firms can indeed generate an acceptable return on investment.

While the province has been making an effort to fill the technology venture funding gap created by the exodus of private capital sources through the activities of Innovation Ontario, this strategy can be dangerous, since without an adequate supply of co-investors, many of these firms will need substantial on-going capital support from government if they are to grow. If this support is not forthcoming, (which it is unlikely to be, given prevailing fiscal conditions), it is quite likely that many of these companies would fail. Government venture groups are also often unable to provide the necessary non-financial support and direction that many of these technology companies badly need and that their competitors in the United States are receiving from their venture capital backers.

Rather than attempting to intervene directly (which in our view would be neither practical nor effective) we believe at least a portion of existing government funding for venture investments and economic development initiatives should be redirected to address the structural impediments constraining the growth of Canadian technology companies.

Ontario definitely needs more venture capital funds ... not just more venture capital, but more funds. Syndicating investments among a number of funds is a time proven method of spreading risks and applying more support to individual technology firms. Syndicating also allows venture investors to learn more quickly from one another and to gain from each other's network of additional capital sources.

Previous research conducted by Venture Economics on the fastest growing Canadian and U.S. companies showed that the average venture capital backed U.S. growth company in the sample received $17 million in venture capital from 11 venture investors over 3 rounds of investment prior to going public. In Canada, the average venture capital firm received 1 round of venture capital totalling $3 million from 1 venture investor. For the Canadian venture capital investor, the inability to syndicate results in much higher risk levels per deal and constrains the scope of the investment opportunity in absolute terms. For Canadian technology entrepreneurs, more funds mean a more competitive market and more chances to convince investors to participate in their companies.

More venture capital funds and more technology focussed venture capital would help to retain the Canadian expertise that has developed, and to increase the probability of combining expertise and capital to create successful technology companies.

We therefore propose that the Ontario government redirect some of the funds now being used for direct venture capital investing and economic development initiatives to seed several new technology focussed venture capital funds.

Such an initiative could be launched by calling for proposals from venture capitalists to manage technology focussed venture capital funds. A review panel, assembled by the government, would select from these proposals in much the same way as a pension fund would decide on a venture fund investment.

The funds selected would be allocated $5-10 million or up to 25% of their target fund size, subject to raising the remaining amount from private sector sources within 6 months. By offering its capital on an advantaged basis, government could directly impact the rates of return achieved by the private sector investors, thereby setting the stage for more private capital to return to the market.

These advantages need not be costly for the government. For example, the government's capital could be made available on a first in-last out basis. The up-front commitment from government will help engender confidence in other prospective investors. By not taking its capital back until all private sector investors have done so, the government would be reducing the holding period for the private investors between drawdown and return of capital by one or more years, and thereby increasing the rate of return.

As an additional inducement, the gains attributable to the government could be at one-half the rate available to the private sector investors. Management of the funds, which would be structured as limited partnerships, would be entitled to its share of gains only after the contributed capital was returned to both the government and private sector investors.

There could be perhaps six of these new funds in Ontario and they would be run as private sector venture funds with no government intervention. They would be required to report to the government as they would to their private sector investors, and would be restricted only in broad, overall terms, although funds intending to focus on technologies related to the environment could be given higher priority. Venture capital managers from the U.S. and abroad should also be encouraged to establish new technology-focussed venture capital funds under this program. In so doing, the government would also be taking steps to strengthen the base of management talent available in the venture capital community.

The cost of such a programme may be less than current direct government intervention and returns would likely be higher. Private sector venture funds typically charge management fees of 2.5% to 3.0% of committed capital per annum. Many of the government venture funding groups in Canada have management costs in the order of 5% to 10% of capital. The

privately managed funds would be able to set their own compensation levels (within their fee structure) and, because of the possibility of sharing in long term investment gains, would be able to ensure the long term continuing involvement of their investment managers.

Proposals to manage these funds could also come from management of existing government venture capital programmes. Within these groups there are a number of talented and experienced venture capitalists, who could form effective fund management groups with private sector investors.

Funds formed in response to this initiative could be encouraged to form close links with government agencies involved in the development and commercialization of environmental and energy related technologies. Selected initiatives which, in our view, would at least start to address the shortages of skilled entrepreneurial managers, knowledgeable technology investors and capital that are impeding the development and success of Canadian technology companies are as follows:

3. Encourage re-investment by Canadian technology entrepreneurs.

Informal private investors can make a valuable contribution to the pool of experienced entrepreneurial managers by providing capital and business support to fledgling technology firms and continuing to provide counsel as the business matures. Given that research has shown that the majority of informal investors are experienced business builders and company founders, these investors can also help offset Canada's shortage of experienced venture capital technology investors.

The investment vehicle of choice for many of these investors has been through the Small Business Development Corporation programme which provides a tax credit to such companies which invest in eligible firms. Since this programme was launched with the intent of encouraging the establishment of local or regional venture capital companies, rather complex safeguards were built in to ensure that the money was invested quickly, in the right types of companies and using certain equity structures.

We encourage the government to re-consider the SBDC programme and to

> *replace it with a simplified programme that would enable informal investors to make direct equity investments in eligible technology businesses and obtain an immediate 30% cash grant in return. The investor would be required to hold his investment in the company for a minimum of four years. The maximum cash grant and the minimum investment level could be adjusted over time to control programme costs and ensure that only serious investments are made.*

7.7 Conclusion

The issues related to encouraging the growth and success of Canadian technology companies are complex, and there are clearly no easy solutions. We believe that these broader initiatives, coupled with the more focused measures in the first set of proposals, could be a first step towards realizing some of the economic potential associated with emerging environmental policies.

To enhance the potential for Ontario technology companies to attract Canadian management talent from that has gone to the U.S. or abroad, we believe government can play an important role in terms of information and awareness classified above. To this end, marketing materials should be developed to explain the technology business and research environment in Canada to foreign executives, and to describe who the players are, what Canada has to offer,

and how they can learn more. Launching such a marketing campaign in co-operation with industry associations or selected technology sectors would enhance its effectiveness (and could be integrated with efforts to draw Canadians back to Canada, as discussed below).

ENDNOTES

[87]Ontario Hydro, *1990 Non-Utility Generation Plan*, Toronto (September 1990)
[88]Acres International, Ltd., *Cogeneration Potential in Ontario and Barriers to its Development*, Ontario Ministry of Energy, Toronto, (February 1987)
[89]Interview with Atlas Polar executive

CHAPTER 8—ROLE OF ENERGY UTILITY REFORM

"Exploiting the full menu of efficiency opportunities can double the quantity and more than halve the cost of savings, because saving electricity is like eating a lobster: if you extract only the large chunks of meat from the tail and claws and throw away the rest, you will miss a comparable amount of tasty morsels tucked in crevices."

Amory Lovins, in a recent article in Scientific American

8.0 Introduction

Reducing CO_2 emissions 20 percent from 1988 levels by 2005 will require an ambitious effort on the part of utilities, government, and the private sector to achieve market penetration of efficiency retrofit programmes in the 50-to-70 percent range for existing buildings and industrial activities, and 100 percent for new ones. While capturing the potential energy savings and avoiding the "lost opportunities" in new buildings and equipment is a matter of political will—the province already has at its disposal many of the regulatory instruments necessary to do the job—the Coalition would agree that achieving high market penetration of efficiency measures in existing building and equipment stocks presents a difficult challenge, given the barriers already enumerated in the sectoral chapters.

This chapter examines the key factors needed for the design and implementation of demand-side management programmes that achieve high participation rates and significant reductions in energy demand. In addition, the rationale and basic elements of law and regulatory reforms needed for utilities to fully participate in implementing a global warming strategy in Ontario are proposed. These include measures to encourage Ontario's utilities to adopt "least cost planning" or "integrated resource management" as the basis for delivery of energy services to the public, including: (i) approaches that could be taken within existing legislation; (ii) suggestions for amendments of the Power Corporation Act and for strengthening the role of the Ontario Energy Board in utility regulation. In addition, the feasibility and desirability of establishing a new energy conservation and renewable energy utility is examined.

8.1 Key Elements of Successful Demand-Side Programs

A recent survey of utility commercial/industrial conservation and load management programs (C&LM) across the U.S. prepared for the New York State Energy Research and Development Authority indicates that typical C&LM programmes are reaching less than five percent of eligible customers and are reducing energy use among those customers by less than 10 percent.[90] While such information seems discouraging, it is important to keep in mind that most U.S. utilities are only now just gearing up such programmes and have only a few years experience with them. Furthermore, this survey, along with another recent one by the U.S. Oak Ridge National Laboratory, did identify a number of programmes that are achieving penetration rates in the order of 70 percent or more of targeted customers at a cost to utilities of $0.04 per kWh saved, even with allowance made for "free riders", customers who would have eventually installed such measures on their own in the absence of incentives from the local utility.[91]

The programmes identified with highest customer participation and energy savings all appear to have common elements. First, they are multiple end-use programs that attempt to address *all* commercial and industrial end uses at once, rather than concentrate on specific end uses on a piecemeal basis. Second, they share common financial and non-financial programme elements:

- ***Financial elements***. Financial incentives that pay 50 percent or more of the direct installation costs of measures are a key to success; in the New York survey these averaged about $0.03 per kWh saved. Varying the level between low and moderate financial incentives apparently has little affect on market penetration.

- ***Non-financial elements***. The most successful programmes are of two types: (i) *comprehensive*, combining multiple marketing techniques, regular personal utility contacts with customers, across-the-board technical assistance, and simple programme procedures and materials, and; (ii) *performance contracting*, in which private energy service companies are paid each year for energy savings based on the utility's full avoided costs. In both approaches, the promotion of new technologies not readily available reduces free riders, although initial participation rates may be lower as customers gain familiarity with them.

Third, top management in utilities offering such programmes typically send a strong message to staff and customers that C&LM programmes will benefit them, with some utilities rewarding managers with bonuses that are linked to goal achievement. Finally, environmental groups are typically involved in such programmes through the "collaborative process", in which utility representatives, environmentalists, and other outside specialists participate in the design and implementation of programs.[92]

A sample of the electricity savings from implementation of the most successful programs with high penetration among targeted customers is shown in the accompanying table.

Table 8 (a): Average Electricity Savings from American Utility End-Use Programs

Utility	Program	Type[1]	Average energy savings
Boston Edison	Design Plus	C	22-23%
Boston Edison	ENCORE	P	15%
Bonneville Power Authority	Commercial incentives pilot	C	12%
Bonneville Power Authority	Purchase of energy savings	P	11%
Northeast Utilities	Energy Action	C	11%
Puget Power and Lighting	Commercial Conservation Financing	C	10-12%
Southern California Edison	Hardware Rebate	R	7%

[1]C=comprehensive; P=performance contracting; R=rebate
Source:Steven Nadel, Lessons Learned: A Review of Utility Experience with Conservation and Load Management Programs for Commercial and Industrial Customers, ACEEE, Washington D.C. (1990)

Keeping in mind that most of these programmes are still at the pilot stage or have only a few years operating experience, they appear to point in the direction that Ontario's utilities and regulatory milieu should go if the provincial government is to follow through effectively on its commitment to the nuclear moratorium and to implement a CO_2 emissions reduction initiative.

The implications for change in Ontario's utilities, however, would be quite significant, pointing towards a regulatory milieu in which "least cost planning" or "integrated resource planning" become the basis for utility demand-supply decisions. Such planning involves consistent assessment of the variety of demand and supply resources to cost effectively meet customer energy service needs, and it includes a number of features not yet common in Ontario:

- explicit consideration of energy efficiency and renewable energy programmes as alternatives to power plants and new supplies of natural gas;
- consideration of complete environmental costs in the pricing of energy;
- active public participation in the planning and implementation of demand-side programs;
- analysis of the uncertainties and risks posed by different resource options and external factors.[93]

None of these elements are yet common to utility regulation, planning, and management in Ontario. Energy efficiency programmes are undertaken largely to satisfy public demand for them, not because they may be inherently the least-cost way to provide a service to customers. Environmental factors are not yet considered in energy pricing policies, as they are now in a number of jurisdictions in the U.S. The public, rather than being involved in the planning and implementation of programmes, is faced with several years of environmental assessment adversarial proceedings. And finally, the variety of risks associated with supply (and demand) options are not analyzed and considered in the regulatory process.

In terms of programme initiatives, the province's largest utility, Ontario Hydro, gives the appearance of moving in the right direction. For instance, it has recently undertaken the Guaranteed Energy Performance Program (GEPP), which offers incentives to performance contractors who guarantee economic performance of electrical energy savings projects. On the surface, the programme resembles the innovative and successful initiatives that American utilities have mounted in recent years, moving away from the piecemeal approach and toward a multiple measure end use approach.

This promising effort as initially designed, however, may achieve only modest market penetration and energy reductions. The application process for performance contractors is complicated and demanding. The incentive funding, up to $700 per kW of peak demand reduction falls far short of the avoided cost incentives now paid by some American utilities, stopping at 50 percent of the costs of a project. And the contractor has to wait a year to recover any costs under the performance option, discouraging capital investment in significant energy measures, while encouraging contractors to opt for the conventional piecemeal prescriptive option because revenue can be earned more quickly under that approach. In fact, the design of the programme appears to run counter to its intention, which is to motivate the private sector to make deep cuts in energy use.

Nonetheless, the GEPP programme is a step in the right direction, and Ontario Hydro will no doubt make improvements in it as managers gain experience with performance contracting. Nonetheless, the faults with the initial programme design, as with so many Ontario Hydro demand-side initiatives, really reflect the attitudes and procedures that are endemic to a large, centralized bureaucracy whose primary mission is to deliver reliable supply to its customers.

Ontario's Hydro's present policy, for instance, is to seek financial leverage in the private sector for energy efficiency, so GEPP and other programmes pay no more than 50 percent of the costs of measures. While this policy stretches the limited funds available for energy efficiency, it also prolongs the treatment of demand-side management as merely one of the expenses of doing business, rather than as a long-term investment designed to avoid new supply. Unless Ontario Hydro is willing to pay fully up to the avoided cost of new supply for demand reducing investments, the market penetration and energy reductions achieved with the measures will understandably continue to be modest in the future.

Comparable issues with respect to the regulatory treatment of Ontario's gas utilities cloud their future ability to market cost effective efficiency measures. Presently, they are regu-

lated in such a way that their financial interest lies in expanding the distribution system for natural gas and in leasing equipment to customers. The only reason the utilities would lease a high efficiency, as opposed to a medium efficiency, gas furnace to their customers is if there is strong demand for it or if there is potential for greater net revenues. Profit is not related to efficiency. And even though installation of air sealing and insulation is likely to prove a more cost effective way to reduce natural gas use for heating, allowing the furnace to eventually be downsized, the utilities have no self-interest to finance such an option. Even simple measures are discouraged. If a customer wants to buy an inexpensive insulation cover for an existing medium efficiency water heater, for instance, it won't be available from the utility because its marketing strategy gives preference to leasing new water heaters.

The Coalition concludes that without fundamental reform of Ontario's electric and gas utilities—and the regulatory milieu in which they operate—the efficiency and renewable energy measures outlined in this report could not be achieved.

The following sections outline the Coalition's suggestions for reform of Ontario's electric and gas utilities and regulatory structure towards providing the people of Ontario with least cost energy services.

8.3 The Ontario Energy Board

In order for Ontario's utilities to adopt least cost planning as their *modus operandi*, a fundamental change in their regulatory milieu needs to occur. The initiatives and reforms heretofore mentioned imply expanded authority for the Ontario Energy Board (OEB) with respect to the regulation of Ontario Hydro and the province's other utilities. The Ontario Energy Board Act (OEBA) establishes the OEB and accords to it various regulatory functions.

The authority of the OEB with respect to Ontario Hydro is very limited at present. The OEB merely requires notification by Hydro in the event that Hydro changes its bulk rates, with the OEB's subsequent review and advice to the Minister of Energy being non-binding.. Secondly, the OEBA allows the Minister of Energy the authority to refer other rate-related matters to the Board. In either case, the Board has no decision-making authority and simply reports to the Minister upon its deliberations. The Coalition believes that the OEB should be regarded as the appropriate institution to regulate a variety of energy-related matters. The major features of this expanded mandate are included below.

Currently, the OEB employs rate making principles for gas utilities such that if Ontario's gas consumption increases then the gas utilities' profits will increase. Consequently, conservation is not in their financial self-interest. However, conservation would be profitable for the gas utilities if the following reforms were adopted by the OEB:

- least-cost rate making mechanisms that encourage conservation;
- establishment of rate making mechanisms that sever the link between a utility's profits and its natural gas throughput volumes;
- financial bonuses for privately held utilities that cost effectively reduce their customers' energy consumption.[94]

Further to the earlier discussion of reforming Ontario Hydro's mandate, amendments should be made which give the OEB binding regulatory control over the Corporation's:

- rates and its rate-setting function, including its buy-back rates;
- Ontario Hydro's systems expansion proposals;
- Ontario Hydro's borrowing programme.

The OEB should be given jurisdiction over the approval of the costs projected for municipalities, municipal Hydro utilities, the Ontario Energy Conservation Corporation or other agencies delivering demand side endeavors. The OEB would evaluate proposals and decide whether Ontario Hydro must pay for them. Similarly, for joint programmes involving gas and electricity conservation the OEB would be responsible for allocating funding between utilities. The same responsibility would arise with respect to multiple fuel projects.

Finally, in order to expand the OEB's role as a major facilitator of public participation in the energy planning process, the following would be in order:

- The OEB would assume responsibility for decisions regarding the regulation of Hydro which are presently reserved for Cabinet. This decision making authority would extend to financial approvals for all Hydro projects and shall be based upon the least cost planning principle outlined earlier;
- The Consolidated Hearings Act, 1981 shall be amended so that the OEB and the Environmental Assessment Board (EAB) would constitute a joint board for the purpose of reviewing provincial energy plans and making recommendations to Cabinet;
- The joint board would also be responsible for handing down decisions regarding Ontario Hydro projects based on the principles of wise environmental management and least cost planning. This would avoid unnecessary duplication of decision making efforts which would occur if the boards met separately.
- Where Ontario Hydro is required to submit an environmental assessment of a proposed undertaking under the Environmental Assessment Act and no hearing is required, the OEB shall not make any decision with regard to the undertaking prior to its approval by the Minister of the Environment.
- The OEB would also continue to have the power now available to it pursuant to the Intervener Funding Project Act to provide funding and assess costs with regard to public participation in any matter within the Board's jurisdiction even if the Act were to be repealed.

8.4 Proposals Which Rely Upon Existing Regulatory Tools

At present, there are two instruments which could be used to achieve some of the initiatives outlined in this chapter and would require neither immediate amendments to existing legislation nor the introduction of new legislation. They include: issuance of a policy statement by Cabinet and/or drafting a memorandum of understanding between the Minister of Energy and Ontario Hydro.

The Cabinet, once it develops a general policy and goals with respect to global warming, should consider directing the Minister of Energy to formulate a memorandum of understanding with Ontario Hydro. The Corporation would be required to use its best efforts to ensure that such exercise broadly conforms to the measures included in the global warming policy. Such a memorandum is presently being prepared by the Ministry with respect to other matters. It makes sense that the goals, targets, and strategies with respect to global warming be also addressed, should the Cabinet be able to reach a consensus on government policy on global warming in a timely fashion.

It is recommended that the memorandum of understanding currently being prepared for implementation include the following measures as part of an initial strategy to reduce CO_2 emissions from power generation:

- Ontario Hydro's planning framework should seek to minimize the total societal economic and environmental costs of its operations;

- In order to significantly reduce Ontario Hydro's CO_2 emissions rate by 2005, much greater emphasis should be placed on the substitution of parallel generation for coal-fired generation to reduce to 10 percent or less of the generation mix, including increasing the buy-back rate to better reflect the avoided cost of centralized nuclear supply;
- Energy efficiency programmes should encourage greater participation of the private sector, along the lines of the GEPP initiative, and the policy of financial leverage that has constrained the effectiveness of Ontario Hydro efficiency initiatives should be abolished in favour of full avoided cost of new supply being offered for efficiency services;
- Ontario Hydro should encourage the participation of the public in designing and implementing its energy efficiency and renewable energy initiatives.

8.5 Amendments to the Power Corporation Act (PCA)

Several amendments to the PCA would be necessary to implement a new conservation strategy for Ontario. Here is a summary.

Since municipal utilities have the most direct contacts with the majority of energy consumers, their involvement in energy efficiency, renewable energy, and cogeneration will be essential to achieving high levels of market penetration. In order to encourage their greater initiative, Ontario Hydro's authority over municipal utilities needs to be modified to decentralize decision-making in several key areas:

- municipal utility rates and charges for supplying power;
- the municipal utilities' borrowing programmes for improvements to a power system;
- the management of surplus funds accrued by municipal utilities;
- the appointment of members to municipal electric utility commissions.

The result of these changes would be to subject the activities of municipal utilities to regulation by the OEB and remove their control from Ontario Hydro. They would be able to undertake their own energy efficiency and power generation projects, which would most likely be small-scale cogeneration initiatives in the commercial sector. They would be able to contract for provision of energy efficiency services to their customers. They would be able to adjust their rates.

Historically, Hydro has enjoyed several advantages over the private sector in fulfilling the requirement of producing and selling "power at cost". Subsidies such as tax exemptions and exemptions from dividend payments should be removed. In addition, the Debt Guarantee Fee should be raised to reflect the full extent of the benefit which accrues to Ontario Hydro from their lower interest rates. If the true cost of electricity is reflected in the prices consumers pay for it then a positive inducement towards energy conservation will be created. True costing will increase the efficiency and accountability of the energy sector. Similarly, buy-back or purchase rates for independent or parallel generation must directly reflect Ontario Hydro's full economic and environmental costs. All of these costs should be listed as allowable costs to be charged by Ontario Hydro under the PCA.

Revisions to the PCA are also required for the purpose of including environmental considerations in all decision-making processes related to power production. Environmental priorities must be accorded the same weight in decision-making as economic priorities. Presently, concerns as to the production of power at cost are restricted to the evaluation of the Corporation's financial or monetary costs. The PCA requires Ontario Hydro to produce power by minimizing financial costs, not the total of social and environmental costs. Therefore, the Act must be amended to allow for consideration of these variables in the decision-making process.

Finally, the PCA, Section 56(b) imposes constraints on Ontario Hydro with respect to the geographical scope of its energy efficiency programmes, loans, etc. and restricts fuel choices for buildings. Program managers at Ontario Hydro, for instance, believe the PCA restricts their offering efficiency programmes in buildings heated with natural gas. And the law expressly forbids switching to natural gas from electrical service. Such provisions should be repealed or amended. The PCA should enable Ontario Hydro to be able to pay the costs of conversion programs conducted by other agencies where required to do so by the Ontario Energy Board or other government policy, and Ontario Hydro's managers should be allowed to offer services to customers who own buildings served with natural gas.

8.6 Need for a Comprehensive Ontario Energy Plan

A broad consensus exists with respect to the long failure of government to provide adequate policy direction to Ontario Hydro, and a commensurate lack of public participation—until the recent environmental assessment process concerning regarding Hydro's demand-supply plan—in Hydro's policy direction. The Corporation's present long-term planning process takes place in a virtual policy vacuum. The role of government, at least in the incipient stages of the electrical system planning process, appears to be only at the invitation of Hydro.

Therefore, it is recommended that a comprehensive energy plan for Ontario be developed and implemented along the following lines for the the various sectors:

- development of a provincial energy plan with comprehensive assessment of environmental, social, and economic effects through a consultation process that involves a broad range of interest groups drawn from community organizations, the public, and private sectors;
- the provincial energy plan would provide for the development of further efficiency, conservation and demand options as have been adopted by other jurisdictions; the plan should direct those engaged in sectoral planning to give priority to, in descending order, conservation, efficiency, demand, and only then supply options;
- the plan, once developed, would be referred to the joint board composed of OEB and EAB members.

8.7 An Energy Conservation and Renewable Energy Utility

The PCA establishes Ontario Hydro as a Crown corporation and sets out the decision-making authority and responsibilities of the Corporation and its Board of Directors. While the Environmental Assessment Act, the Ontario Energy Board Act, and other provincial and federal statutes are of some relevance with regard to Ontario Hydro's activities, the PCA provides the basis for the contract that this province has with the corporation, identifying the rights, duties, and obligations of the arrangement. The Act establishes the purposes and business of Ontario Hydro as including the generation, transmission, distribution, supply, sale and use of power. In addition, Ontario Hydro is responsible for the provision of energy conservation programmes.

In the Coalition's view, Ontario Hydro at present is not naturally predisposed to planning or implementing the ambitious energy efficiency and renewable energy programmes needed to achieve the aims of CO_2 reduction and the nuclear moratorium. It is large, highly centralized, and by corporate self-interest and expertise mostly oriented towards the provision of capital-intensive energy supply. On the other hand, the majority of cost effective conservation and energy efficiency measures are small, decentralized, and technologically simple, basically at odds with Ontario Hydro's corporate culture. While there are many dedicated, highly motivated, and skilled managers working in the energy efficiency area, the

market penetration and effectiveness of their initiatives are unduly constrained by corporate policies.

The adoption of a least cost planning mandate will require a fundamental change in Ontario Hydro's corporate culture. The most important change will be decentralization, meaning significant facilitation of the role that municipal utilities, municipalities, and a variety of private sector energy service companies and neighborhood organisations play in energy conservation programmes. There will be more vice presidents of customer service, and individual employees will have more independence and authority to make decisions. Meanwhile, over time the role of engineers will decline, while the importance of psychologists and market researchers will rise.[95]

Some members of the Coalition are skeptical that such a fundamental change in corporate mandate and culture will ever take place at Ontario Hydro, primarily because it is a monopoly whose bureaucratic self-interest is naturally to resist change. Hence, alternative approaches to the delivery of energy efficiency measures and renewable energy programmes to the public also need to be explored.

One possibility would be the establishment of a new utility in Ontario whose mandate would expressly be to provide such measures and programmes. Such a utility would offer several advantages.[96] The primary one is that its mandate would be clear—the achievement of energy savings and development of renewable energy—and its revenues would be directly proportional to the success of its initiatives. Ontario Hydro and the gas utilities, however, would be in no way be precluded from pursuing energy efficiency measures.

The new utility would have a number of disadvantages, however. The market barriers to getting conservation and renewable technologies into homes and businesses could be greater, since it would take time to build public visibility and trust. There would also be the danger that the measures, once installed in homes and businesses, would not be well maintained. The new utility would have to be structured in such a way so that local municipal utilities and neighborhood organizations assume a prominent role in the delivery of programmes at the community level. Finally, it would take precious time for the new agency to be set up and to gain credibility with the public.

Once under way, the new utility would offer a full range of research and development initiatives, products, services, and performance contracts aimed at improving the energy efficiency of existing and new buildings, equipment, and processes, including:

- energy surveys and audits to identify the economic potential of the full range of retrofit technologies available;
- extensive education and training of performance contractors, private and municipal energy inspectors, building managers, etc.;
- financing in a wide variety of forms and forums, including performance contracting, leasing, grants, loans, and rebates, to motivate the private sector to adopt energy efficiency and renewable technologies and achieve the economic potential that has been identified and targeted;
- technology development and commercialization to nurture Canadian technical innovations and entrepreneurship, including strategic research and development and venture capital initiatives designed to attract and leverage private investment.

The new utility would be funded at the full avoided cost of new energy supply by Ontario Hydro and the province's gas utilities, a rate to be determined by the Ontario Energy Board. Additional revenues would be generated by the leasing of equipment, such as solar water heaters, to customers. And the new corporation would be free to form joint ventures and

other collaborations with private enterprise to commercialize and market new technologies. The more efficiency and renewable energy it were able to sell, the higher the utility's revenues would be, while competition would ensure the public receives services and products at the least economic cost to them, up to the cost of new supply.

8.8 Conclusion

In conclusion, Ontario utilities should have a key role to play in the implementation of a provincial global warming strategy. As presently structured, however, the utilities would not be able, in the view of the Coalition, to achieve the 50-70 percent market penetration of efficiency measures with respect to existing buildings, equipment, and processes outlined heretofore in this report. The primary reason is that energy efficiency and renewable energy measures are not presently enough in the corporate self-interest of the utilities, despite the fact that such measures are economic and pay back handsomely in saved energy costs. The regulatory agency, furthermore, has neither the right mandate nor the power to guide the utilities to change.

The Coalition favours law and regulatory reforms to change the way utilities plan, operate, and finance themselves, as well as to improve public participation in utility planning. Such reforms would ensure that energy efficiency and renewable energy measures pay back to the utilities, and ultimately to the rate payers, thus improving the chances that the economic savings that are possible with such measures can be translated into energy and CO_2 savings over the long-term. As a hedge against the difficulties of achieving such fundamental reform, however, the Ontario government should seriously explore the feasibility, costs, and the potential rewards and risks involved in establishing a new conservation and renewable energy utility.

ENDNOTES

[90]Steven Nadel, *Lessons Learned: A Review of Utility Experience with Conservation and Load Management Programs for Commercial and Industrial Customers*, American Council for an Energy-Efficient Economy, Washington, D.C. (April 1990)
[91]Linda Berry, *The Market Penetration of Energy-Efficiency Programs*, Oak Ridge National Laboratory, ORNL/CON-299, Oak Ridge, Tennessee (April 1990)
[92]William B. Ellis, *The Collaborative Process in Utility Resource Planning*, Public Utilities Fortnightly, June 22, 1989
[93]Eric Hirst, et. al., *Integrated Resource Planning for Electric and Gas Utilities*, In ACEEE Proceedings of 1990 Summer Study on Energy Efficiency in Buildings, Washington D.C. (1990)
[94]Jack Gibbons, "Switching Tactics," The Globe and Mail, April 16, 1991
[95]Eric Hirst, *Possible Effects of Electric-Utility DSM Programs, 1990-2010*, Oak Ridge National Laboratory, ORNL/CON-312 (January 1991)
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CHAPTER 9—SUMMARY AND CONCLUSIONS

"A respect for planet earth, a respect for our fellow citizens around the world, and our love for our families to follow, all require that both as individuals and as a society we must consumer fewer resources, even if we want and would like to consume more. Changing doesn't just mean changing other people. It means changing ourselves, changing our communities, changing our companies, changing how we produce things, distribute them, and get rid of the waste."

Bob Rae, preface to *Greening the Party; Greening the Province (1990)*

9.0 Summary of CO_2 Reductions

Measures that the Coalition deems economically attractive to society have been identified to reduce CO_2 emissions in Ontario's residential, commercial, transportation, and industrial sectors, and they are described in Chapters 2-6. The following highlights the most significant measures:

Residential Sector

- all new houses are built to the standard of the Advanced House in Brampton by 2005, i.e., they will use one-third the energy of today's new houses;
- space heating needs in 75 percent of existing homes are cut by 25 percent by 2005 by retrofitting a combination of air sealing, insulation, improved windows, and high efficiency furnaces;
- electric appliances will be replaced by models 20-to-40 percent more efficient;
- thirty percent of existing homes will get their domestic hot water from solar hot water heaters.

Commercial Sector

- all new commercial buildings will use half the energy per metre of floorspace as the existing stock of buildings by 2005;
- space heating needs in 50 percent of the commercial building stock are cut by 20 percent by 2005;
- high efficiency lighting retrofit in 75 percent of the existing building stock reduces electricity use from lighting loads by 60 percent;
- a reduction in energy use from plug load of 20 percent by 2005, through efficiency improvements in office equipment, computers, etc.;
- downtown Toronto buildings connected to the city's district heating system are cooled during the summer with cold lake water using a concept called Freecool.

Transportation Sector

- a combination of gas guzzler taxes and sipper rebates are introduced and gradually increased annually to improve the on-road fuel economy of passenger cars in Ontario from the present 11.4 litres per 100 kilometers to 6.7 litres per 100 kilometres by 2005;
- public transit ridership in the Greater Toronto Area is doubled through land use controls that create an urban boundary around Metro to encourage higher densities and significant new investments in rapid rail transport, utilizing the region's underutilized railway corridors;
- 650,000 natural gas vehicles are on the roads by 2005;
- ethanol manufactured from woody biomass is used in a 10 percent blend for all gasoline autos.

Industrial Sector

- all wood used for energy in the pulp and paper industry is cultivated on a 100 percent renewable basis, permitting the CO_2 directly emitted to be reabsorbed in biomass growth that occurs as a result selective harvesting practices that allow natural regeneration combined with adequate silviculture, which assumes present practices are not sustainable;
- industrial heat is cut 25 percent, and cogeneration's full economic potential is realized;
- motive power use is cut an average of 27 percent throughout industry.

These and other measures result in a net reduction by 2005 of 31 megatonnes (Mt) emissions from a 1988 base of 125 Mt, a reduction of 25 percent by 2005 from that base. At least half of the reductions stem from a significant cut in the CO_2 emissions rate of electricity due to the substitution of natural gas cogeneration for coal-fired power, as well as demand-side measures in the electricity sector. The analysis covers about 75 percent of the province's total CO_2 emissions base. The results are summarized in Table 9 (a).

Table 9 (a)—Summary of Estimated Ontario's CO_2 Reductions, 1988-2005

Sector	1988 energy *PJ*	1988 CO_2 *Mt*	2005 energy *PJ*	2005 CO_2 *Mt*	Amount reductions *Mt*	% change
Residential	473	29.3	453	19.3	10	-34%
Commercial	188	11.9	205	6.5	6	-46%
Transportation	295	20.0	223	13.5	6	-33%
Industry	925	63.3	971	54.1	10	-15%
TOTAL[1]	1,881	124.5	1,852	93.4	32	-25%
Ontario Total[2]	2,576	164.3				

[1]75 percent of the province's CO_2 emissions base
[2]100 percent of the province's CO_2 emissions base (Ministry of Energy data—Appendix A)

The following sub-sectors, which account for about 25 percent of the province's CO_2 base in 1988, are not included in the analysis:

- the "other" category of the commercial energy sector, accounting for about 31 percent of the sector's energy use in 1988;
- freight and passenger rail, airplane, and marine transportation, a total of about 53 percent of the energy use in transportation sector in 1988;
- non-energy uses of fossil fuels, such as feedstock for chemical processes, accounting for about two percent of the province's CO_2 emissions in 1988.

If the availability of data, time, and resources had permitted, the Coalition's research team would have followed several lines of inquiry with respect to these particular areas.

In the commercial sector, Ontario's Hydro's data were employed, since this sector is the most electricity intensive of all the sectors, and we would expect Ontario Hydro's end use breakdowns to be carefully researched. There is a significant difference, however, between Ontario Hydro's and the Ministry of Energy's estimates of energy use in the commercial sector, with Ontario Hydro's estimates 44 percent lower than the Ministry's estimates (apart from their different treatment of multi-residential buildings). The difference is accounted for by the "other" category in the Ministry's estimates. It would be worthwhile to explore why there are such differences, and attempt to resolve them.

In the transportation area, future trends in the energy intensity of inter-city and urban truck freight transport will have a significant effect on CO_2 emissions in this sector. While freight has been shifting from rail to more energy intensive modes such as trucks, substantial efficiency improvements have occurred within each mode. The overall truck freight efficiency improved by 20 percent between 1970 and 1985 in the U.S., for instance, and comparable gains are feasible over the next 15 years for the North American truck fleet, since commercial owners pay more attention to life-cycle costs than do passenger car owners.[97] The Ministry of Energy projects a 20 percent improvement in fuel efficiency of inter-city diesel trucks only. Extension of this efficiency measure to the overall truck fleet would appear to be a reasonable measure, but it needs more research.

In addition, urban fleet trucks consist of many vans, and they could be converted economically to natural gas or, in a few years, to electricity. The United Parcel Service in the U.S. recently announced conversion of their entire fleet of delivery vans to natural gas, and southern California's South Coast Air Quality District is coordinating the purchase of 10,000 electric vans, some of which may be supplied by an Ontario company. Extension of the province's alternative fuel vehicle programme, which has concentrated mostly on development of an urban bus, to trucks and vans could be a promising avenue to encourage further CO_2 reductions in the freight sub-sector.

Regional passenger and freight rail should also be explored further. While the population densities and distances outside of the urban centres may not permit inter-city rail on the scale typically found European countries, particular "niche" rail corridors may be viable. With respect to airplane and marine transportation, on the other hand, the province would not appear to have any policy tools at its disposal to affect the energy intensities of these modes, which are likely to be mostly influenced by larger economic forces.

Finally, the potential for reducing energy use from the pursuit of other environmental objectives needs to be explored. The three Rs of waste management—recycling, reuse, and reduction—may offer significant opportunities for energy reduction. For instance, many studies indicate that refillable glass bottles use half the energy that nonrefillables, even when energy used for transporting the bottles and adding lids and labels are taken into account. The potential for saving energy in Ontario from policies that encourage reuse, as well as recycling and reduction, merit special attention.

9.1 Priority Measures and Policies

Three broad strategies are explored in each sector: efficiency, fuel switching, and renewable energy. Each of the three strategies can make an important contribution to reducing CO_2 emissions.

- ***Efficiency strategies.*** A significant role is played by new provincial regulations and market incentives/disincentives that seek to ensure that new buildings, passenger automobiles sold in Ontario, and industrial equipment and processes capture as much economically attractive efficiency as possible. Improvements in the efficiency of space heating play, perhaps, the most important role in reducing CO_2 emissions in buildings. This assumes a much higher profile for present regulatory instruments, such as the Energy Efficiency Act and the provincial building code. Implementation of the Act, for instance, would need to be extended to a much wider variety of products, equipment, and processes, while the energy provisions in the provincial building code would have to be upgraded biennially, rather than every five years.

- ***Fuel switching.*** The substitution of high efficiency natural gas cogeneration for coal-fired electricity generation at full economically achievable levels (3,833 megawatts of new capacity by 2005) is required to lower the CO_2 emissions rate of electricity generation by more than half. As a result of this switch in the electricity sector, the switch to natural gas from electricity for space and water heating in buildings has only a marginal effect on CO_2 reductions. The switch from oil to natural gas for space and water heating, however, has a more significant effect. Fuel switching from gasoline and diesel fuel to natural gas only has a marginal impact on CO_2 emissions, reflecting a low market penetration (10 percent) of natural gas vehicles assumed in the analysis, although it has other beneficial environmental effects, such as the abatement of urban air pollution.

- ***Renewable energy.*** Ethanol blends for passenger cars and passive and active solar space heating in residences make an important contribution to CO_2 reduction, as does the use of wood cultivated on a sustainable basis for energy use, as a waste, in the pulp and paper industry. It is difficult to precisely estimate the contribution of passive solar and other renewable technologies, such as advanced windows, to residential space heating, especially in homes built 1995-2005, but the contribution is assumed to become progressively larger as the efficiency standards for new buildings are upgraded.

In the industry sector, we assume that the sector's energy demand grows at the historic 20-year rate of 2.1 percent average each year, rather than the Ministry of Energy's forecast rate of 2.6 percent. The reason is that we believe the Free Trade Agreement and other international economic factors will spur structural changes in the province's economy that favour more rapid growth of less energy intensive manufacturing and industries. It is a trend that has been evident through the 1980s that is likely to continue, if not accelerate, after the present recession. The lower rate of energy demand growth, therefore, does not necessarily assume lower economic growth, but rather an further decoupling of economic and energy demand growth. Our assumption lowers the growth in CO_2 emissions from this sector, compared with the Ministry of Energy's forecasts.

In all of the other sectors, the analysis assumes the Ministry's forecasts for growth, say, in the number of new buildings or passenger automobiles. As explained in the introductory chapter (section 1.6), however, we disagree with the Ministry's industry sector forecasts, which were made before the recession and a number of important world events, such as the unification of Germany and the Middle East war, which are likely to have long-term implications for the world economy.

9.3 Implications for the Nuclear Moratorium

As a result of the efficiency and fuel switching measures assumed in the analysis, electricity demand in Ontario grows about 31 percent from 1988 to 2005 (see Appendix F). Allowing for Ontario Hydro's assumption that a 24 percent reserve margin is needed, new capacity by 2005 is met by the new Darlington A units, new hydraulic capacity now in the planning stages, and natural gas cogeneration. As a result, coal-fired power generation declines six-fold.

Key to the achievement of a 20 percent reduction in CO_2 emissions by 2005 is the substitution of natural gas cogeneration for coal-fired generation in Ontario Hydro's electricity supply mix, as well as aggressive electricity conservation in all the sectors. These measures, if continued beyond 2005, should enable Ontario to avoid the need for any new nuclear or other central power plants. Indeed, the moratorium calls for even more stringent efficiency and fuel switching measures than those assumed in this report's analysis.

In the residential and commercial sectors, for instance, electric space and water heating are switched to natural gas in only 20 and five percent from their respective energy bases. These are fairly conservative assumptions that should be more aggressive for a nuclear moratorium scenario. They aren't higher here because the marginal reduction in CO_2 achieved wouldn't appear to justify the cost of higher fuel switching targets given present energy prices, i.e., as future electricity demand is reduced further, the CO_2 emissions rate for electricity approaches the emissions rate of natural gas heating (assuming coal is displaced by natural gas as the fuel of choice for electricity generation). On the other hand, were the environmental costs of electricity supply reflected in the price, more aggressive fuel switching would no doubt be more economical.

Looking beyond 2005, there will be a need for new renewable energy sources to counterbalance the growth of natural gas cogeneration, in order to keep the CO_2 emissions rate from electricity generation as low as possible. While such a long-term strategy is beyond the scope of this report, the Coalition believes that the generation of electricity from wood biomass, other biomass sources such as municipal and industrial wastes, solar photovoltaic cells, active and passive solar heating, and small scale hydro will constitute significant sources over the long-term.

The development of these resources, together with continuing aggressive conservation measures, should enable the province to meet long-term electricity demand while reducing emissions of CO_2 and reducing dependence on nuclear capacity. The Coalition does not believe, therefore, that nuclear capacity is needed over the long-term to meet a provincial CO_2 reduction target, provided the development of renewable energy receives the highest priority.

In two sectors, however, transportation and industry, strategies to reduce CO_2 do imply greater electricity use. In urban centres, particularly the Greater Toronto Area, the substitution of electrified rapid rail for passenger automobiles would add marginally, perhaps several petajoules, to provincial electricity demand. In industry, particularly iron and steel, the increasing use of electricity intensive processes such as electric arc furnaces will reduce CO_2, but add even more significantly to electricity demand.

On balance, the Coalition believes that the nuclear moratorium and a provincial global warming strategy that seeks to reduce CO_2 emissions by 20 percent would be mutually reinforcing over the next 15-to-20 years, and that nuclear capacity will not be needed over the long-term to meet CO_2 reduction targets.

9.4 The Role of Energy Prices

Energy prices and their change over time have a bearing on energy consumption and investment in efficiency measures. Future prices are difficult, if not impossible to forecast, however, and they seldom reflect the true costs of energy supply. Furthermore, energy prices do not necessarily reflect an equilibrium between demand and supply in the "classical" meaning of economic rules. Prices often reflect political goals and policies meant to enhance the financial interest of a national or group of industries.

For instance, OPEC's price policies are deliberately formulated to avoid stimulating too much conservation or renewable energy in industrial economies, which might displace oil over the long-term. If prices were too low (as they might be in the absence of an international cartel), they would lead to regulatory policies in countries like the U.S. to stem dependence on foreign oil as their domestic oil production dried up. If prices were too high, they would stimulate "natural conservation" and development of renewable energy sources. So OPEC keeps its prices in a "medium" range to keep other nations, especially the U.S., from taking any deliberate action at all to restrict imports or to stimulate much energy conservation.

Energy prices also do not reflect the hidden burdens of energy production, distribution, and consumption, including environmental, health, and a variety of other "external" costs. In Canada it has long been a tenet of public policy that low energy prices are good for an economy based on resource extraction industries, while mega-projects are good for jobs, so government subsidies have flowed to the oil and gas sectors, hydro dams, and to the nuclear industry. Increasingly, however, it is being recognized, and the Coalition certainly believes, that if we are to depend more on the market to achieve least-cost solutions to environmental problems, the true costs of energy must prevail in the market. Therefore, "external" prices must be reflected in the price of energy, and if precise values for environmental, health, and other costs are difficult to determine, "placeholder" values that represent an honest best guess should be used.

Higher energy prices, however, may have significant social and economic effects. High gasoline taxes, for instance, are a burden on the people who live in northern Ontario, who often must drive their automobiles and trucks long distances in order to make a living. And higher electricity rates hurt low-income homeowners, who may be more dependent on electric heating because of its lower capital cost.

The Coalition, in the foregoing sectoral analyses, places emphasis on the need for new taxes or fees that establish incentives and disincentives to encourage consumers to purchase more energy efficient vehicles, appliances, or homes at the original point of sale. From an equity point of view, we believe this approach is superior to energy taxes because it gives consumers a choice, and they are rewarded with a rebate in many cases if they choose a more efficient option. There is a large debate in the economics community, beyond the scope of this paper, as to whether point of sale incentives of disincentives or energy taxes are a more effective in changing consumer behaviour. From the government's point of view, the point of sale approach may not be as desirable because it does not typically raise new revenues, since the taxes or fees that are collected are returned to consumers in the form of rebates. We believe, however, this approach should receive serious consideration because, in theory, "feebates" should effectively change consumer behaviour, and they should be more attractive to the public, because they allow people to "win" if they make the right choice.

This paper does not address the question of a carbon tax, in part because a recent study for the Ministry of Energy already covers this subject very well.[98] (The Ministry should consider publicly releasing the study to encourage more debate concerning this important issue.) Furthermore, there is not a consensus among members of the Coalition regarding the desirability for a provincial carbon tax. Concerns centre mainly on the potential social and regional inequities of such a tax, and whether any government, once establishing the tax as a new revenue source, would be willing to target a good portion of the revenues to offset inequities and to further encourage the environmental goals of the tax by offering rebates to sectors or targeting revenues on activities, such as technological research and development, that merit special support.

In sum, while the Coalition recognizes the importance of energy prices and taxes in encouraging efficiency and renewable energy sources, the issue is not fully explored in this paper. In the immediate future, however, the Coalition believes that "feebates", a combination of taxes or fees and rebates to encourage the purchase of more efficient vehicles, appliances, and buildings, would give the provincial government an important new tool to encourage energy efficiency through the market. The province's gas guzzler tax, for example, would be the place to start. While extending the tax to cover all light-duty vehicles, the revenue collected, rather than going into the treasury, should be rebated to people who buy more efficient vehicles. This change should allow the programme to be extended to northern Ontario by adding light-duty pick-up trucks, since people who purchase the most efficient pick-up trucks available will be rewarded.

9.5 Need for a Provincial Global Warming Industrial Strategy

A major effort over the next 15 years to reduce the energy intensity of the province's economy and to reduce CO_2 emissions will create important opportunities for technological and economic advancement. Recent studies of international competitiveness show that nations with the most rigorous environmental standards often lead in the export of the affected products. Germany, for instance, leads in the export of air pollution control equipment and processes, in part because its stationary air quality standards are among the most stringent in the world. Japan, on the other hand, has become a leader in the production of fuel efficient automobiles in part because of long standing policies that tax large engine blocks. (Since Japan is totally reliant on foreign oil, this is more of an energy security, than an environmental policy.)

Both countries are now moving to cash in on what they see as an emerging world-wide market for new CO_2 abatement technologies. In perhaps the technological coup of the 1990s, Germany facilitated Siemen's acquisition of ARCO Solar for a purported $30 million. While ARCO Solar has been the biggest U.S. producer of photovoltaics (PVs) and perhaps the world leader in new, thin-film technologies, its sale reflects the lack of an industrial strategy in the U.S. to capitalize on its own technical infrastructure. What Siemens (and Germany) want is ARCO's copper indium diselenide (CIS) technology, which in the past two years has established new efficiency and stability standards for thin film PVs. While production costs remain a key uncertainty, many experts believe that CIS manufacture using proven low-cost techniques for producing amorphous silicon shouldn't be a problem. Recent discussions between Siemens and Bayernwerke, a utility in Bayerne, Germany, appear to have centered on the possibility of building a CIS manufacturing on a site previously to be used for a nuclear reprocessing plant.[99] With its commitment to a 30 percent reduction in CO_2 emissions by 2005, Germany's facilitation role in this deal clearly indicates the influence that its global warming strategy has had on industrial policy. Germany views PV technologies playing an important role in meeting its own targets, as a start towards gearing up to meet demand in a booming world market in PVs in the years ahead.

Japan's industrial policy is also supporting the development of global warming and urban air pollution abatement technologies. Research on the global environment figured prominently in budget requests for 1991 submitted by Japan's Ministry of International Trade and Industry (MITI). Most of the funding will go towards development of CFC substitutes and technology to absorb and utilize CO_2, projects that will be undertaken by the new Research Institute of Innovative Technology for the Earth that is expected to open in 1992 in the new Kansai science city between Kyoto and Osaka.[100] Meanwhile, after nine years of intensive research, development, and demonstration by MITI, the fuel cell is about to be commercialized in Japan. Since fuel cells are the most environmentally benign fossil fuel technology now available, they will replace the diesel cogenerators that provide electricity and heat for many office buildings, primarily because air quality regulations governing emissions in urban centres are expected to become more strict.[101] A consortium of Japanese and American companies is already offering a 200 kilowatt unit, and Fuji Electric Co. now offers a 50 kW unit and has 35 orders from utilities in Japan and Europe.[102]

There is no reason why Ontario cannot follow the same path as Germany and Japan, indeed, many opportunities will open up, should the province decide to link an industrial renewal strategy to its global warming strategy. For instance, the consortium that is commercializing the 200 kW fuel cell is establishing a new manufacturing facility at Pratt and Whitney complex in Middletown, Connecticut. But location of the consortium's permanent engineering

and production facility have not been decided, and such a decision will rest primarily on the course of business development over the next few years.

For the sake of argument, why not Canada? Why not a partnership between Ontario Hydro and/or several municipal utilities to create a substantial internal domestic market for fuel cells, leading to establishment of the consortium's headquarters in Ontario? Whether or not fuel cells should figure prominently or not in Ontario's energy supply future, a question that is beyond the scope of this inquiry, the bright road ahead for this technology and others, such as thin film PVs, speak eloquently for the strategic opportunities for technological and economic advancement that could lie ahead for Ontario.

There are a number of generic policy initiatives that the province could undertake to encourage investment in the development and commercialization of technologies that can contribute to the reduction of CO_2 emissions. Such initiatives should be able to support the exploitation of near term opportunities, like expanded use of cogeneration technologies in the commercial and industrial sectors, and the development of new technologies and applications that will give Ontario a competitive advantage in the longer term, such as fuel cells or PVs. Such initiatives include:

- establishment of a strategic procurement programme to support the market penetration of environmental-related technologies produced by local firms;
- encouragement of the formation of new pools of venture capital to invest in early stage technology companies, especially directed towards addressing the structural impediments that presently constrain the growth of Canadian technology companies, by redirecting some of the provincial funds now being used for direct venture capital to seed several new technology focussed venture capital funds;
- encouragement of investment by informal Canadian technology entrepreneurs, by replacing the Small Business Development Corporation programme with a simplified program that would enable informal investors to make direct equity investments in eligible technologies.

In sum, the government needs to rethink the ways it presently uses venture capital and technology development funds, which presently do not reach the entrepreneurs pioneering new energy demand or supply technologies and which are not yet capitalizing on the international opportunities that are growing in the U.S., Europe, and Japan.

9.6 Need for Utility Reform

Utilities will need to play a key role in implementing a provincial global warming strategy, requiring an ambitious effort on their part, as well as government and the private sector, to retrofit existing buildings and industrial activities with efficiency measures. Market penetration of efficiency measures on the order of 50-to-70 percent over the next 15 years will be necessary to reach the Toronto target.

The key elements required for such an effort include: financial incentives that pay up to the full avoided cost of new supply for direct installation of efficiency measures; comprehensive programmes that address all specific end uses at once, rather than on a piecemeal basis; decentralized programme delivery that emphasizes personal contacts with customers through local municipal utilities and neighborhood organisations; and the public and customer participation in the design of efficiency programmes.

Presently, utility energy efficiency programmes contain few of these elements, and we do not believe that under the present regulatory climate in Ontario the province's utilities are likely to move much beyond their current efforts, which are not likely to achieve high market

penetration. Even when utilities attempt to innovate—Ontario Hydro's ambitious Guaranteed Energy Performance Program (GEPP) is a step in the right direction—corporate policy may tend to undermine the effort in the long term. In the case of GEPP, Ontario Hydro's corporate policy of seeking financial leverage in the private sector for efficiency, while it stretches the funds available for efficiency measures, prolongs the treatment of demand-side initiatives as an expense of doing business, rather than as a long-term investment seeking to avoid new supply. Only up to 50 percent of the costs are covered by the programme, and the limit of $700/kW of peak demand reduction falls far short of Ontario Hydro's real avoided costs for new electricity generation.

In the Coalition's view, what is needed in Ontario are fundamental reforms that create a regulatory milieu in which "least cost planning" or "integrated resource planning" become the basis for utility demand-supply options. Such planning involves the continuing assessment of the variety of demand and supply resources to cost effectively meet customer energy service needs. Steps in this direction call for:

- Strengthening the Ontario Energy Board's regulatory authority with respect to electricity policy and mandating the Board to pursue the implementation of least cost rate making mechanisms for all provincial utilities that give them greater financial incentives to invest in demand-side programmes;
- Incremental steps using existing regulatory rules, such as a memorandum of understanding between Ontario Hydro and the Cabinet, to set out a framework for minimizing Ontario Hydro's total societal economic, and environmental costs;
- Amendments to the Power Corporation Act to decentralize electricity rates and borrowing decisions to enable municipal utilities to assume a greater role; and to give Ontario Hydro greater flexibility with respect to the choice of fuel use, allowing it to implement efficiency and cogeneration programmes in gas territories;
- Formulation of a comprehensive provincial energy plan for the various energy sectors;
- Consideration of a new energy conservation and renewable energy utility to plan and implement energy efficiency and renewable energy programmes throughout the province.

These initiatives will not only improve the prospects for achieving significant provincial CO_2 reductions by 2005, by increasing the market penetration of energy efficiency and renewable programmes sponsored by utilities, but they would be essential in any case, the Coalition believes, to implement the nuclear moratorium.

9.7 Conclusion

The purpose of this report—the product of two months of consultation among the Coalition's members, government officials, and private sector executives—is to suggest strategies, measures, and specific programmes that, if they could be undertaken, would enable Ontario to undertake a credible effort to achieve a 20 percent reduction in CO_2 emissions from 1988 levels by 2005. Although our rough quantitative analysis indicates that the Toronto target may be economically attractive at least with respect to the sectors and sub-sectors that were examined in depth, we wish to emphasize that the report does not address in detail the extent of the programmes needed nor the costs of the investments required. Further study much beyond the scope of this effort is obviously required.

We do, however, conclude that the changes that would be needed in energy production, distribution, and use in Ontario (as well as the management of natural resources such as forests that provide feedstock for energy processes) are very significant. In the electricity sector, for instance, we assume that the economic potential of cogeneration and demand reducing measures that can be achieved are roughly double what Ontario Hydro presently states is feasible.

The Coalition believes, however, that the provincial government has at its disposal a variety of regulatory and market tools to encourage significant reductions in CO_2 in the residential, commercial, transportation, and industrial sectors. New tools will also be needed, however, especially in the regulation of operation of electric and gas utilities and in the implementation of a provincial industrial strategy to capitalize on its global warming strategy for the purposes of technological and economic advancement. With all of these tools at its disposal and sufficient political will and leadership, the province should be able to undertake an effective effort to abate future emissions of CO_2, while opening important new technological and economic advancement for the people and industries of Ontario.

Here are the key policy initiatives the Coalition believes are necessary to credibly launch a provincial global warming during the next few years:

- ***The Ontario Energy Board (OEB).*** The Premier's Office gives the OEB regulatory scope and leadership to require provincial electric and gas utilities to adopt a least cost planning mandate and more authority over Ontario Hydro's and municipal electric utilities rates, which would give a significant push to a host of energy efficiency measures that cost less to society than the provision of new supply.

- ***Promotion of Cogeneration.*** The Premier's Office requests Ontario Hydro to further increase the buy-back rate to accelerate the development of cogeneration projects, and the OEB establishes a new regulatory framework for gas utilities that encourages them to actively develop local cogeneration projects.

- ***The Provincial Building Code.*** The Ministry of Housing reviews and revises the provincial building code on a biennial, as opposed to five-year, basis. In the residential sector the R2000 standard is adopted for all new housing, while in the commercial sector the ASHRAE 90.1 code plus more stringent lighting standards along the line of those contained in the California energy code would be adopted.

- ***The Energy Efficiency Act.*** The Ministry of Energy raises the profile of the Act, expands its scope to include a variety of residential products, such as windows, furnace fans, etc., not now covered, as well as commercial and industrial equipment, and adds the staff necessary to do the job.

- ***Gas Guzzler/Sipper Rebate Program.*** The Ministry of Treasury and Economics modifies the recently strengthened provincial gas guzzler tax, changing it into an environmental, as opposed to a revenue producing tax, that aims to provide rebates to people who purchase fuel efficient automobiles, with the tax and rebates scaled to the fuel efficiency of the motor vehicle.

- ***Move Towards Ethanol.*** The Ministry of Agriculture and Food, working with the Ministry of the Environment and the farming community, seek to develop the regulatory basis for promoting in an environmentally responsible strategy for using Ontario-cultivated ethanol as an octane enhancer in gasoline.

- ***Urban Boundary Zone and Public Transit.*** The Ministry of Municipal Affairs, working with the Ministry of the Environment, develop a province-wide initiative comparable to Oregon's that seeks to better manage the growth of urban centres so as to increase densities and control the conversion of valuable farm land and natural areas to urban use. In addition, the Ministry of Transportation works with Metro and neighboring governments to develop and implement a plan to double public transit ridership in the Greater Toronto Area by 2005.

- ***Cap on Industrial CO_2 Emissions***. The Ministry of the Environment in consultation with industry review the various options available and select an appropriate regulatory approach to stabilise CO_2 emissions from the largest 50-100 industrial emitters 1988 levels by 2005. The Ministry of Energy, in consultation with Ontario Hydro, other appropriate agencies, and particular energy-intensive industries such as iron and steel develop plans for technical and financial assistance to facilitate the capacity of such industries to incorporate energy efficiency and cogeneration technologies to reduce their energy use, as well as their factor costs associated with such use.

- ***Development of an Industrial Strategy***. The Ministry of Industry, Trade, and technology, working with the Ministry of Energy, Ontario Hydro and the gas utilities, seek to formulate an energy efficiency and renewable energy industrial strategy for Ontario that would make the province an exciting and rewarding place for private venture capitalists to invest in new energy technologies and industries. An initial opportunity worth exploring would be to develop a strategy to gain as much leverage from the venture capital fund that British Gas will be setting up under its agreement with the provincial government as part of the condition of sale of Consumers Gas.

We believe, in conclusion, that adoption of the Toronto target as a provincial planning goal can be an instrumental tool of public policy that establishes a framework in which sectoral energy intensity and fuel mix targets and specific strategies can be formulated, relative progress can be measured over the years, and political leverage can be gained in national and international negotiations. More importantly, such a commitment would put the province in a league with a small, but fast growing international community of governments that recognizes the potentially vast implications of global climate change and are willing to step forward and do something about it.

ENDNOTES

[97]Office of Technology Assessment, *Changing by Degrees: Steps to Reduce Greenhouse Gases*, Washington, D.C. (February 1991)
[98]Jack Gibbons and Marcia Valiante, *Carbon Taxes and Tradeable Carbon Quotas: A Least Cost Strategy to Reduce Ontario's Carbon Dioxide Emissions*, Canadian Institute for Environmental Law and Policy, Toronto (January 1991)
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[100]"David Swinbanks, *Japanese Science Budget: A Darker Shade of Green*, Nature, Vol. 346, August 30, 1990, p. 783
[101]Noboru Itoh, *New tricks for an old power source—The Japanese mount a major effort to make fuel cells commercially viable*, IEEE Spectrum, September 1990, p. 40
[102]*UTC, Toshiba, and IFC Announce Production of 200-kW Fuel Cell Powerplants*, Fuel Cell News, Vol, VII, No. 2, June, 1990

Table A-1: Ontario Energy Use, 1988 (PJ)

Secondary energy	Oil	Natural Gas	NGLs	Coal	Wood/ Waste	Sub-total	Elec-tricity	Total
Residential	64	244	11	–	19	338	147	485
Commercial	43	151	3	–	–	197	137	334
Industrial	95	349	6	205	71	726	177	903
Transportation	606	1	10	–	–	617	1	619
Non-energy	174	32	30	–	–	235	–	235
SUB-TOTAL	982	776	61	205	90	2,114	462	2,576
Own uses/losses	87	60	–	–	–	147	41	
TOTAL	1,069	836	61	205	90	2,361	503	2,576
Primary energy								
Electricity:								
Fossil	8	9	–	347	–	364		
Hydro	–	–	–	–	–	382		
Nuclear	–	–	–	–	–	705		
SUB-TOTAL						1,450		
TOTAL PRIMARY	1,077	845	61	552	90	3,711		

Table A-2: Ontario CO_2 Emissions, 1988 (Mt)

End-use:	Oil	Natural Gas	NGLs	Coal	Wood/ Waste	Total	% of total
Residential	4.7	12.1	.7	–	1.6	19.0	12%
Commercial	3.2	7.5	.2	—	–	10.9	7%
Industrial	7.1	17.3	.4	18.2	7.1	50.1	30%
Transportation	41.8	.03	.6	–	–	42.4	26%
Non-energy	–	.8	–	–	–	.8	.5%
Own uses/losses	5.8	3.0	.02	—	–	8.9	5%
SUB-TOTAL	62.5	40.8	1.9	18.2	8.7	132.0	80%
Electricity	.6	.5	–	31.3	–	32.3	20%
TOTAL CO_2	63.1	41.2	1.9	49.5	8.7	164.3	100%

Table A-3: Ontario Energy Use, 2005 (PJ)

Secondary energy	Oil	Natural Gas	NGLs	Coal	Wood/ Waste	Sub-total	Elec-tricity	Total
Residential	45	275	12	–	21	352	202	554
Commercial	31	206	4	–	–	241	213	454
Industrial	131	522	10	323	99	1,085	300	1,385
Transportation	782	5	12	–	–	799	2	801
Non-energy	245	70	46	–	–	360	–	235
SUB-TOTAL	1,234	1,078	84	323	120	2.838	716	3,194
Own uses/losses	93	88	1	–	–	182	63	
TOTAL	1,327	1,156	85	323	120	3,020	779	3,799
Primary energy								
Electricity:								
Fossil	2	90	–	216	2	309		
Hydro	–	–	–	–	–	436		
Nuclear	–	–	–	–	–	1,234		
Purchases	–	–	–	–	–	74		
SUB-TOTAL	1,077	845	61	552	90	2,052		
TOTAL PRIMARY	1,329	1,255	85	540	121	5,072		

Table A-4: Ontario CO_2 Emissions, 2005 (Mt)

End-use:	Oil	Natural Gas	NGLs	Coal	Wood/ Waste	Total	% of total
Residential	3.3	13.6	.7	–	1.7	19.3	10%
Commercial	2.3	10.2	.2	–	–	12.8	7%
Industrial	9.7	25.9	.6	28.7	9.9	74.9	38%
Transportation	53.9	.3	.7	–	–	54.9	28%
Non-energy	–	1.7	–	–	–	1.7	.1%
Own uses/losses	6.3	4.4	.04	—	–	10.7	5%
SUB-TOTAL	73.5	56.2	2.3	28.7	11.6	174.3	88%
Electricity	.1	4.5	–	19.5	–	24.1	12%
TOTAL CO_2	75.6	60.6	2.3	48.2	11.6	198.4	100%

APPENDIX B—RESIDENTIAL SECTOR

Potential CO_2 reductions in the residential sector are estimated using end-use and fuel share data for single-family residences from Ontario Hydro's *Market Reference Dataset*, Energy Management Branch (February 1990), which is shown in Table B-1, and the report, *Commercial Sector End-Use Forecast* (December 1990), which includes estimates of commercial floor space (Table C-2) and energy use by sub-sector and end-use (Table C-4). Ontario Hydro classifies multi-family residential space as commercial space in its record keeping, and references are to be found in Appendix C—Commercial Sector. The projection of the number of residential units added from 1989-2005, however, are Ministry of Energy estimates, and they are given in Table B-9.

Ontario Hydro's estimates of secondary energy end-use in single and multi-family residential buildings in 1988, 472 PJ, are approximate to the Ministry's estimate of 484 PJ. The Ontario Hydro data is used here, however, because it permits finer resolution in the application of CO_2 reduction measures, particularly to different appliance categories. It is assumed that the reduction estimates derived from analysis of the Ontario Hydro data are applicable to the Ministry's data.

Measures applied to multi-family residential buildings are described in Appendix B. The economically achievable measures assumed to reduce CO_2 emissions in single-family residences include the following:

RETROFIT TARGETS (2005) FOR SINGLE-FAMILY RESIDENCES:

Efficiency scenario:

- Improvements in thermal envelope and furnaces reduce heating energy in 70 percent of the building stock by....25%
- Reduction in cooling energy in all buildings by....25%
- Significant penetration of compact fluorescents reduces lighting energy by....60%
- Improvement in average efficiency of water heater stock of....25%
- Improvement in average efficiency of refrigerator stock of....40%
- Improvement in average efficiency of clothes dryer stock of....25%
- Improvement in average efficiency of cooking appliance stock of....20%
- Electric heat pumps average 200 percent efficiency in the following percentage of homes that presently have heat pumps....75%

Fuel switching scenario:

- Switch from oil to gas space and water heating by....50%
- Switch from electricity to gas space and water heating by....20%

Renewable scenario:

- Retrofit domestic solar water heating in 30 percent of building stock, saves.... 22 PJ
- Retrofit passive solar heating technologies, such as attic heat return, in 10 percent of building stock, saves....16 PJ

ENERGY INTENSITY TARGET FOR NEW RESIDENTIAL:

It is assumed that the average energy intensity of new residences, as a result of biennial modification of the provincial building code, declines gradually to 40 GJ for a typical 2,000 sq. ft. home (equivalent to the energy rating of the Advanced House) from the present code standard of about 125 GJ for an equivalent sized house. The same proportional decline is applied to row houses. The decline occurs in the following steps (per unit of housing):

	1989-90	1991-92	1993-95	1996-99	2000+
Detached + semi	150 GJ	125	100[1]	60	40[2]
Row	110 GJ	90	70	45	30

[1]R2000; [2]Advanced House

The average energy intensity of new multi-family residences declines 50 percent from the average level of the 1988 multi-family building stock by 2005. Hence, apartment stock constructed 1988-2005 would average .4 GJ/m² or 8 kWh/ft² in 2005. Details are provided on new multi-family residential buildings in Appendix B tables. The incremental cost of building the Advanced House today is $20,000; this cost would be expected to decline as some of the components built especially for the House, such as the integrated mechanical system, reach commercialization. One caveat is in order. These projections do not assume increasing use of electric appliances in the future, a continuing trend that will tend to increase home energy use in the future. On the other hand, the calculations are conservatively based on a 2,000 square foot house, somewhat larger than what is likely to be the average size of new homes over the next 15 years, so they probably tend to overestimate future energy use.

The results of the measures on CO_2 emissions spreadsheet analysis are shown for existing buildings in Tables B-5-to-B-8, and for single-family residences in Table B-10. As a result of the measures described above, CO_2 emissions are reduced by 34 percent from 1988 levels. The results are summarized in the following table:

Table B-1: Summary of CO2 Reduction Measures in Residential Sector

Scenario applied	Total energy use *PJ*	Total energy CO2 *Mt*
Base (1988):		
Single-family	423.12	26.32
Multi-family	49.59	2.95
TOTAL 1988	472.71	29.27
Scenarios for existing:		
Single-family		
(i) efficiency	332.19	15.81
(ii) fuel switch	332.19	15.49
(iii) renewable	294.01	14.61
Multi-family		
(i) efficiency	38.06	1.57
(ii) fuel switch	38.06	1.56
(iii) renewable	38.06	1.38
Sub-Total existing		
(i) efficiency	370.25	17.38
(ii) fuel switch	370.25	17.05
(iii) renewable	332.07	15.99
New Residential:		
Single-family	64.08	3.00
Multi-family	9.70	0.31
Sub-total new	73.78	3.31
TOTAL 2005	405.85	19.29

Most of the reduction indicated is due to: (i) revisions in the building code to make new buildings progressively more efficient; (ii) retrofit measures, such as air sealing, insulation, and efficiency furnaces to reduce heating requirements of the existing residential building stock, and (iii) greater appliance efficiency. The changes in electricity use and emissions from such use are summarized in Table B-12.

Table B-2: Residential Energy Consumption (base case), 1988-2005

	Single family		Multi- family		Total	Total
	1988	2005	1988	2005	1988	2005
Space heating	**274.21**	**295.08**	**27.95**	**38.94**	**302.16**	**334.03**
electric	39.02	53.33	6.13	8.54	45.15	61.87
gas	161.07	181.29	20.51	28 58	181.59	209.87
oil	52.82	37 47	1.31	1 82	54 13	39.29
solar	0.00	0.00	0.00	0.00	0.00	0.00
other	21.29	22.99	0.00	0.00	21.29	22.99
Water heating	**72.19**	**86.04**	**7.37**	**10.27**	**79.56**	**96.31**
electric	23.48	32.09	2.42	3.37	25 90	35.46
gas	46.60	52.45	4.89	6.81	51.48	59.26
oil	2.11	1.50	0.07	0.09	2.18	1.59
solar	0.00	0.00	0.00	0.00	0.00	0.00
Cooking	**12.57**	**15.96**	**1.74**	**2.42**	**14.31**	**18.38**
electric	8.05	11.00	1.71	2.38	9.76	13.38
gas	1.65	1.85	0.03	0.04	1.67	1.89
other	2.88	3.11	0.00	0.00	2.88	3.11
Clothes drying	**8.42**	**11.26**	**0.00**	**0.00**	**8.42**	**11.26**
electric	7.38	10.09	0.00	0.00	7.38	10.09
gas	1.04	1.18	0.00	0.00	1.04	1.18
Appliances	**37.81**	**51.68**	**7.81**	**10.88**	**45.62**	**62.56**
air conditioning	7.43	10.16	1.81	2.52	9.24	12.68
air humidify	0.36	0.50	0.39	0.54	0.75	1.03
refrigeration	16.59	22.67	2.58	3.60	19.17	26.26
lighting	8.26	11.29	3.03	4.23	11.30	15.52
television	5.17	7.07	0.00	0.00	5.17	7.07
Miscellaneous	**17.91**	**23.65**	**4.72**	**6.58**	**22.63**	**30.23**
electric	15.03	20.54	4.64	6.46	19.66	27.00
other	2.88	3.11	0.09	0.12	2.97	3.23
Totals	**423.12**	**483.68**	**49.59**	**69.09**	**472.71**	**552.77**
electricity	130.77	178.73	22.70	31.63	153.47	210.36
gas	210.36	236.77	25.43	35.43	235.79	272.19
oil	54.94	38.97	1.38	1.92	56.31	40.88
misc.	27.05	29.21	0.09	0.12	27.14	29.33

Note: Includes single-family residences built, 1989-2005

Table B-3: Residential Energy Consumption (efficiency), 1988-2005

	Single family 1988	Single family 2005	Multi- family 1988	Multi- family 2005	Total 1988	Total 2005
Space heating	**274.21**	**219.40**	**27.95**	**31.78**	**302.16**	**251.17**
electric	39.02	25.36	6.13	6.40	45.15	31.77
gas	161.07	132.89	20.51	23.95	181.59	156.84
oil	52.82	43.58	1.31	1.42	54.13	45.00
solar	0.00	0.00	0.00	0.00	0.00	0.00
other	21.29	17.57	0.00	0.00	21.29	17.57
Water heating	**72.19**	**54.14**	**7.37**	**8.38**	**79.56**	**62.52**
electric	23.48	17.61	2.42	2.56	25.90	20.17
gas	46.60	34.95	4.89	5.75	51.48	40.70
oil	2.11	1.58	0.07	0.07	2.18	1.65
solar	0.00	0.00	0.00	0.00	0.00	0.00
Cooking	**12.57**	**10.06**	**1.74**	**2.08**	**14.31**	**12.14**
electric	8.05	6.44	1.71	1.84	9.76	8.28
gas	1.65	1.32	0.03	0.23	1.67	1.55
other	2.88	2.30	0.00	0.00	2.88	2.30
Clothes drying	**8.42**	**6.32**	**0.00**	**0.00**	**8.42**	**6.32**
electric	7.38	5.54	0.00	0.00	7.38	5.54
gas	1.04	0.78	0.00	0.00	1.04	0.78
Appliances	**37.81**	**24.36**	**7.81**	**9.34**	**45.62**	**33.70**
air conditioning	7.43	5.58	1.81	2.16	9.24	7.73
air humidify	0.36	0.36	0.39	0.46	0.75	0.82
refrigeration	16.59	9.95	2.58	3.09	19.17	13.04
lighting	8.26	3.30	3.03	3.63	11.30	6.93
television	5.17	5.17	0.00	0.00	5.17	5.17
Miscellaneous	**17.91**	**17.91**	**4.72**	**5.65**	**22.63**	**23.56**
electric	15.03	15.03	4.64	5.55	19.66	20.57
other	2.88	2.88	0.09	0.11	2.97	2.99
Totals	**423.12**	**332.19**	**49.59**	**57.22**	**472.71**	**389.41**
electricity	130.77	94.34	22.70	25.69	153.47	120.03
gas	210.36	169.93	25.43	29.94	235.79	199.87
oil	54.94	45.16	1.38	1.49	56.31	46.65
misc.	27.05	22.75	0.09	0.11	27.14	22.86

Note: Does not include single-family residences built, 1989-2005

Table B-4: Residential Energy (fuel switch), 1988-2005

	Single family 1988	Single family 2005	Multi- family 1988	Multi- family 2005	Total 1988	Total 2005
Space heating	**274.21**	**219.40**	**27.95**	**31.78**	**302.16**	**251.17**
electric	39.02	20.29	6.13	6.40	45.15	26.69
gas	161.07	159.75	20.51	23.95	181.59	183.70
oil	52.82	21.79	1.31	1.42	54.13	23.21
solar	0.00	0.00	0.00	0.00	0.00	0.00
other	21.29	17.57	0.00	0.00	21.29	17.57
Water heating	**72.19**	**54.14**	**7.37**	**8.38**	**79.56**	**62.52**
electric	23.48	14.09	2.42	2.56	25.90	16.65
gas	46.60	39.26	4.89	5.75	51.48	45.01
oil	2.11	0.79	0.07	0.07	2.18	0.86
solar	0.00	0.00	0.00	0.00	0.00	0.00
Cooking	**12.57**	**10.06**	**1.74**	**2.08**	**14.31**	**12.14**
electric	8.05	6.44	1.71	1.84	9.76	8.28
gas	1.65	1.32	0.03	0.23	1.67	1.55
other	2.88	2.30	0.00	0.00	2.88	2.30
Clothes drying	**8.42**	**6.32**	**0.00**	**0.00**	**8.42**	**6.32**
electric	7.38	5.54	0.00	0.00	7.38	5.54
gas	1.04	0.78	0.00	0.00	1.04	0.78
Appliances	**37.81**	**24.36**	**7.81**	**9.34**	**45.62**	**33.70**
air conditioning	7.43	5.58	1.81	2.16	9.24	7.73
air humidify	0.36	0.36	0.39	0.46	0.75	0.82
refrigeration	16.59	9.95	2.58	3.09	19.17	13.04
lighting	8.26	3.30	3.03	3.63	11.30	6.93
television	5.17	5.17	0.00	0.00	5.17	5.17
Miscellaneous	**17.91**	**17.91**	**4.72**	**5.65**	**22.63**	**23.56**
electric	15.03	15.03	4.64	5.55	19.66	20.57
other	2.88	2.88	0.09	0.11	2.97	2.99
Totals	**423.12**	**332.19**	**49.59**	**57.22**	**472.71**	**389.41**
electricity	130.77	85.74	22.70	25.69	153.47	111.44
gas	210.36	201.11	25.43	29.94	235.79	231.05
oil	54.94	22.58	1.38	1.49	56.31	24.07
misc.	27.05	22.75	0.09	0.11	27.14	22.86

Note: Does not include single-family residences built, 1989-2005

Table B-5: Residential Energy (renewable), 1988-2005

	Single family 1988	Single family 2005	Multi- family 1988	Multi- family 2005	Total 1988	Total 2005
Space heating	**274.21**	**219.40**	**27.95**	**31.78**	**302.16**	**251.17**
electric	39.02	18.26	6.13	6.40	45.15	24.67
gas	161.07	143.77	20.51	23.95	181.59	167.73
oil	52.82	19.61	1.31	1.42	54.13	21.03
solar	0.00	21.94	0.00	0.00	0.00	21.94
other	21.29	15.81	0.00	0.00	21.29	15.81
Water heating	**72.19**	**54.14**	**7.37**	**8.38**	**79.56**	**62.52**
electric	23.48	9.86	2.42	2.56	25.90	12.42
gas	46.60	27.48	4.89	5.75	51.48	33.23
oil	2.11	0.55	0.07	0.07	2.18	0.62
solar	0.00	16.24	0.00	0.00	0.00	16.24
Cooking	**12.57**	**10.06**	**1.74**	**2.08**	**14.31**	**12.14**
electric	8.05	6.44	1.71	1.84	9.76	8.28
gas	1.65	1.32	0.03	0.23	1.67	1.55
other	2.88	2.30	0.00	0.00	2.88	2.30
Clothes drying	**8.42**	**6.32**	**0.00**	**0.00**	**8.42**	**6.32**
electric	7.38	5.54	0.00	0.00	7.38	5.54
gas	1.04	0.78	0.00	0.00	1.04	0.78
Appliances	**37.81**	**24.36**	**7.81**	**9.34**	**45.62**	**33.70**
air conditioning	7.43	5.58	1.81	2.16	9.24	7.73
air humidify	0.36	0.36	0.39	0.46	0.75	0.82
refrigeration	16.59	9.95	2.58	3.09	19.17	13.04
lighting	8.26	3.30	3.03	3.63	11.30	6.93
television	5.17	5.17	0.00	0.00	5.17	5.17
Miscellaneous	**17.91**	**17.91**	**4.72**	**5.65**	**22.63**	**23.56**
electric	15.03	15.03	4.64	5.55	19.66	20.57
other	2.88	2.88	0.09	0.11	2.97	2.99
Totals	**423.12**	**294.01**	**49.59**	**57.22**	**472.71**	**351.23**
electricity	130.77	79.49	22.70	25.69	153.47	105.18
gas	210.36	173.36	25.43	29.94	235.79	203.29
oil	54.94	20.17	1.38	1.49	56.31	21.65
misc.	27.05	20.99	0.09	0.11	27.14	21.10
solar	0.00	38.18	0.00	0.00	0.00	38.18

Note: Does not include single-family residences built, 1989-2005

Table B-6: Residential CO2 Emissions (base),1988-2005

	Single family		Multi- family		Total	Total
	1988	2005	1988	2005	1988	2005
Space heating	**16.12**	**14.72**	**1.54**	**1.76**	**17.66**	**16.48**
electnc	2.73	1.33	0.43	0.21	3.15	1.54
gas	7.97	8.97	1.01	1.41	8.98	10.38
oil	3.86	2.74	0.10	0.13	3.96	2.87
solar	0.00	0.00	0.00	0.00	0.00	0.00
other	1.56	1.69	0.00	0.00	1.56	1.69
Water heating	**4.92**	**3.90**	**0.54**	**0.49**	**5.45**	**4.39**
electric	1.64	0.80	0.17	0.08	1.81	0.88
gas	2.30	2.59	0.24	0.34	2.55	2.93
oil	0.15	0.11	0.00	0.01	0.16	0.12
solar	0.00	0.00	0.00	0.00	0.00	0.00
Cooking	**0.82**	**0.40**	**0.12**	**0.06**	**0.94**	**0.46**
electnc	0.56	0.27	0.12	0.06	0.68	0.33
gas	0.08	0.05	0.00	0.00	0.08	0.05
other	0.17	0.08	0.00	0.00	0.17	0.08
Clothes drying	**0.57**	**0.28**	**0.00**	**0.00**	**0.57**	**0.28**
electnc	0.52	0.25	0.00	0.00	0.52	0.25
gas	0.05	0.03	0.00	0.00	0.05	0.03
Appliances	**2.64**	**1.29**	**0.55**	**0.27**	**3.19**	**1.56**
air conditioning	0.52	0.25	0.13	0.06	0.65	0.32
air humidify	0.03	0.01	0.03	0.01	0.05	0.03
refrigeration	1.16	0.56	0.18	0.09	1.34	0.65
lighting	0.58	0.28	0.21	0.11	0.79	0.39
television	0.36	0.18	0.00	0.00	0.36	0.18
Miscellaneous	**1.26**	**0.74**	**0.33**	**0.17**	**1.59**	**0.91**
electnc	1.05	0.51	0.32	0.16	1.37	0.67
other	0.21	0.23	0.01	0.01	0.22	0.24
Totals	26.32	21.32	3.07	2.75	29.40	24.07
electncity	9.14	4.45	1.59	0.79	10.72	5.23
gas	10.40	11.64	1.26	1.75	11.66	13.39
oil	4.02	2.85	0.10	0.14	4.12	2.99
misc.	1.95	1.99	0.01	0.01	1.95	2.00

Note: Does not include single-family residences built, 1989-2005

Table B-7: Residential CO2 Emissions (efficiency),1988-2005

	Single family 1988	Single family 2005	Multi- family 1988	Multi- family 2005	Total 1988	Total 2005
Space heating	**16.12**	**11.68**	**1.54**	**1.32**	**17.66**	**13.00**
electric	2.73	0.63	0.43	0.14	3.15	0.78
gas	7.97	6.57	1.01	1.08	8.98	7.66
oil	3.86	3.19	0.10	0.09	3.96	3.28
solar	0.00	0.00	0.00	0.00	0.00	0.00
other	1.56	1.29	0.00	0.00	1.56	1.29
Water heating	**4.92**	**2.53**	**0.54**	**0.34**	**5.45**	**2.87**
electric	1.64	0.44	0.17	0.06	1.81	0.49
gas	2.30	1.73	0.24	0.25	2.55	1.98
oil	0.15	0.12	0.00	0.00	0.16	0.12
solar	0.00	0.00	0.00	0.00	0.00	0.00
Cooking	**0.82**	**0.25**	**0.12**	**0.02**	**0.94**	**0.27**
electric	0.56	0.16	0.12	0.02	0.68	0.18
gas	0.08	0.03	0.00	0.01	0.08	0.04
other	0.17	0.06	0.00	0.00	0.17	0.06
Clothes drying	**0.57**	**0.16**	**0.00**	**0.00**	**0.57**	**0.16**
electric	0.52	0.14	0.00	0.00	0.52	0.14
gas	0.05	0.02	0.00	0.00	0.05	0.02
Appliances	**2.64**	**0.61**	**0.55**	**0.15**	**3.19**	**0.75**
air conditioning	0.52	0.14	0.13	0.05	0.65	0.19
air humidify	0.03	0.01	0.03	0.01	0.05	0.02
refrigeration	1.16	0.25	0.18	0.03	1.34	0.28
lighting	0.58	0.08	0.21	0.06	0.79	0.14
television	0.36	0.13	0.00	0.00	0.36	0.13
Miscellaneous	**1.26**	**0.59**	**0.33**	**0.07**	**1.59**	**0.65**
electric	1.05	0.37	0.32	0.06	1.37	0.43
other	0.21	0.21	0.01	0.01	0.22	0.22
Totals	**26.32**	**15.81**	**3.07**	**1.89**	**29.40**	**17.70**
electricity	9.14	2.35	1.59	0.42	10.72	2.77
gas	10.40	8.35	1.26	1.34	11.66	9.70
oil	4.02	3.30	0.10	0.10	4.12	3.40
misc.	1.95	1.56	0.01	0.01	1.95	1.57

Note: Does not include single-family residences built, 1989-2005

Table B-8: Residential CO2 Emissions (fuel switch),1988-2005

	Single family		Multi- family		Total	Total
	1988	2005	1988	2005	1988	2005
Space heating	**16.12**	**11.29**	**1.54**	**1.31**	**17.66**	**12.60**
electric	2.73	0.50	0.43	0.14	3.15	0.64
gas	7.97	7.90	1.01	1.13	8.98	9.03
oil	3.86	1.59	0.10	0.05	3.96	1.64
solar	0.00	0.00	0.00	0.00	0.00	0.00
other	1.56	1.29	0.00	0.00	1.56	1.29
Water heating	**4.92**	**2.60**	**0.54**	**0.34**	**5.45**	**2.94**
electric	1.64	0.35	0.17	0.05	1.81	0.40
gas	2.30	1.94	0.24	0.26	2.55	2.20
oil	0.15	0.06	0.00	0.00	0.16	0.06
solar	0.00	0.00	0.00	0.00	0.00	0.00
Cooking	**0.82**	**0.25**	**0.12**	**0.02**	**0.94**	**0.27**
electric	0.56	0.16	0.12	0.02	0.68	0.18
gas	0.08	0.03	0.00	0.01	0.08	0.04
other	0.17	0.06	0.00	0.00	0.17	0.06
Clothes drying	**0.57**	**0.16**	**0.00**	**0.00**	**0.57**	**0.16**
electric	0.52	0.14	0.00	0.00	0.52	0.14
gas	0.05	0.02	0.00	0.00	0.05	0.02
Appliances	**2.64**	**0.61**	**0.55**	**0.15**	**3.19**	**0.75**
air conditioning	0.52	0.14	0.13	0.05	0.65	0.19
air humidify	0.03	0.01	0.03	0.01	0.05	0.02
refrigeration	1.16	0.25	0.18	0.03	1.34	0.28
lighting	0.58	0.08	0.21	0.06	0.79	0.14
television	0.36	0.13	0.00	0.00	0.36	0.13
Miscellaneous	**1.26**	**0.59**	**0.33**	**0.07**	**1.59**	**0.65**
electric	1.05	0.37	0.32	0.06	1.37	0.43
other	0.21	0.21	0.01	0.01	0.22	0.22
Totals	**26.32**	**15.49**	**3.07**	**1.89**	**29.40**	**17.38**
electricity	9.14	2.13	1.59	0.41	10.72	2.55
gas	10.40	9.90	1.26	1.39	11.66	11.29
oil	4.02	1.65	0.10	0.05	4.12	1.70
misc.	1.95	1.56	0.01	0.01	1.95	1.57

Note: Does not include single-family residences built, 1989-2005

Table B-9: Residential CO2 Emissions (renewable),1988-2005

	Single family		Multi- family		Total	Total
	1988	2005	1988	2005	1988	2005
Space heating	**16.12**	**10.71**	**1.54**	**1.27**	**17.66**	**11.98**
electric	2.73	0.45	0.43	0.13	3.15	0.58
gas	7.97	7.11	1.01	1.05	8.98	8.16
oil	3.86	1.43	0.10	0.05	3.96	1.48
solar	0.00	0.55	0.00	0.05	0.00	0.60
other	1.56	1.16	0.00	0.00	1.56	1.16
Water heating	**4.92**	**2.30**	**0.54**	**0.31**	**5.45**	**2.61**
electric	1.64	0.25	0.17	0.04	1.81	0.29
gas	2.30	1.36	0.24	0.20	2.55	1.56
oil	0.15	0.04	0.00	0.00	0.16	0.04
solar	0.00	0.40	0.00	0.04	0.00	0.45
Cooking	**0.82**	**0.25**	**0.12**	**0.02**	**0.94**	**0.27**
electric	0.56	0.16	0.12	0.02	0.68	0.18
gas	0.08	0.03	0.00	0.01	0.08	0.04
other	0.17	0.06	0.00	0.00	0.17	0.06
Clothes drying	**0.57**	**0.16**	**0.00**	**0.00**	**0.57**	**0.16**
electric	0.52	0.14	0.00	0.00	0.52	0.14
gas	0.05	0.02	0.00	0.00	0.05	0.02
Appliances	**2.64**	**0.61**	**0.55**	**0.13**	**3.19**	**0.74**
air conditioning	0.52	0.14	0.13	0.03	0.65	0.17
air humidify	0.03	0.01	0.03	0.01	0.05	0.02
refrigeration	1.16	0.25	0.18	0.03	1.34	0.28
lighting	0.58	0.08	0.21	0.06	0.79	0.14
television	0.36	0.13	0.00	0.00	0.36	0.13
Miscellaneous	**1.26**	**0.59**	**0.33**	**0.07**	**1.59**	**0.65**
electric	1.05	0.37	0.32	0.06	1.37	0.43
other	0.21	0.21	0.01	0.01	0.22	0.22
Totals	**26.32**	**14.61**	**3.07**	**1.80**	**29.40**	**16.41**
electricity	9.14	1.98	1.59	0.37	10.72	2.35
gas	10.40	8.52	1.26	1.25	11.66	9.78
oil	4.02	1.47	0.10	0.05	4.12	1.52
misc.	1.95	1.43	0.01	0.01	1.95	1.44

Note: Does not include single-family residences built, 1989-2005

Table B-10: Breakdown of Energy Intensity and New Dwellings, 1989-2005

	1988 Units	1988 GJ/unit	1988 Energy Total	New units 1989	New units 1990	New units 1991-95	New units 1996-2000	New units 2001-2005	Total 1989-2005
Single detached	2032571	169	344	46792	42810	241501	226067	185250	742420
Semi-detached	323936	169	55	4538	4152	26900	23981	19565	79136
Row	193782	123	24	7339	6715	29278	34773	28369	106474
Apartments	960766	52	50	23578	21571	126812	112540	91816	376317
Total	3511055	134	472	82247	75248	424491	397361	325000	1304347

Table B-11: CO2 Reduction Scenario for New Single Family Residential

	1988 Energy Base PJ	1988 share %	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total	CO2 2005
Space Heat	321.80	66%	4.63	4.24	4.37	3.52	3.52	3.52	3.52	2.06	2.06	2.06	2.06	1.37	1.13	1.13	1.13	1.13	1.13	42.53	2.27
Oil	62.50	13%	1.07	0.98	0.85	0.85	0.68	0.68	0.68	0.40	0.40	0.40	0.40	0.27	0.22	0.22	0.22	0.22	0.22	8.76	0.64
Gas	201.40	42%	2.90	2.65	2.73	2.20	2.20	2.20	2.20	1.29	1.29	1.29	1.29	0.86	0.70	0.70	0.70	0.70	0.70	26.62	1.32
Electricity	40.10	8%	0.58	0.53	0.54	0.44	0.44	0.44	0.44	0.26	0.26	0.26	0.26	0.17	0.14	0.14	0.14	0.14	0.14	5.30	0.13
Solar	0.00	0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	17.80	4%	0.26	0.23	0.24	0.19	0.19	0.19	0.19	0.11	0.11	0.11	0.11	0.08	0.06	0.06	0.06	0.06	0.06	2.35	0.18
Water heat	76.60	16%	1.10	1.01	1.04	0.84	0.84	0.84	0.84	0.49	0.49	0.49	0.49	0.33	0.27	0.27	0.27	0.27	0.27	10.12	0.43
Oil	1.30	0%	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.17	0.01
Natural gas	51.20	11%	0.74	0.67	0.69	0.56	0.56	0.56	0.56	0.33	0.33	0.33	0.33	0.22	0.18	0.18	0.18	0.18	0.18	6.77	0.33
Electricity	23.60	5%	0.34	0.31	0.32	0.26	0.26	0.26	0.26	0.15	0.15	0.15	0.15	0.10	0.08	0.08	0.08	0.08	0.08	3.12	0.08
Solar	0.00	0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	0.50	0%	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00
Space cooling	1.40	0%	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.19	0.00
Electricity	1.40	0%	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.19	0.00
Appliances	85.10	18%	1.23	1.12	1.15	0.93	0.93	0.93	0.93	0.54	0.54	0.54	0.54	0.36	0.30	0.30	0.30	0.30	0.30	11.25	0.29
Gas	2.50	1%	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.33	0.02
Electricity	81.90	17%	1.18	1.08	1.11	0.90	0.90	0.90	0.90	0.52	0.52	0.52	0.52	0.35	0.29	0.29	0.29	0.29	0.29	10.82	0.27
Other	0.70	0%	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.01
TOTAL	484.90	100%	6.98	6.39	6.58	5.30	5.30	5.30	5.30	3.10	3.10	3.10	3.10	2.06	1.70	1.70	1.70	1.70	1.70	64.08	3.00

Table B-12: Summary of Changes in Residential Electricity Use, 1988-2005

	1988 Energy PJ	2005 Energy PJ	1988 CO2 Mt	2005 CO2 Mt
Existing buildings:	153.47	91.52	10.72	10.72
Single-family	130.77	79.49	9.14	9.14
Multi-family	22.70	12.03	1.59	1.59
New buildings:	n/a	22 42	0.00	0.56
Single-family	n/a	19.43	n/a	0.48
Multi-family	n/a	2.99	n/a	0.07
Sub-totals				
Single-family	130.77	98.92	9.14	9.62
Multi-family	22.70	15.03	1.59	1.66
TOTAL	153.47	113.94	10.72	11.28

APPENDIX C—COMMERCIAL SECTOR

Potential CO_2 reductions are estimated using data from a recent Ontario Hydro report, *1990 Commercial Sector End-Use Forecast* (December 1990), which includes estimates of floor space (Table C-2) and energy use by sub-sector and end-use (Table C-4). Annual growth rates of individual sub-sectors, however, are Ministry of Energy estimates, and they are given in Table C-1, which consolidates the Ontario Hydro data for floor space and energy use and shows energy intensities. Fuel shares from the Ministry's data are also used for the 1988 building stock (Table C-3).

Ontario Hydro's estimates of energy use in the commercial sector differ from the Ministry's estimates, largely due to a large "other" category in the Ministry's database. The Ontario Hydro data is used here because it permits finer resolution in the application of CO_2 reduction measures. It is assumed that the reduction estimates derived from analysis of the Ontario Hydro data are applicable to the Ministry's data, though it is recognized this simplifying assumption may overlook subtleties connected with energy use in the Ministry's "other" category.

The economically achievable measures assumed to reduce CO_2 emissions include the following:

RETROFIT TARGETS FOR EXISTING BUILDINGS:

Efficiency scenario:

- •Improvements in thermal envelope and furnaces reduce heating energy in 50 percent of the building stock by....20%
- •Reduction in cooling energy in 50 percent of the building stock by....20%
- •Level Three lighting retrofits reduce electricity loads in 75 percent of building stock by....60%
- •Reduction in ventilation energy by retrofitting efficient motors in 50 percent of building stock by....25%
- •Reduction in water heating in 50 percent of building stock by....25%
- •Reduction in cooking energy in 50 percent of building stock by....20%
- •Reduction in plug load energy in 100 percent of buildings by 20%*

Fuel switching scenario:

- •Switch from oil to gas space and water heating by....50%
- •Switch from electricity to gas space and water heating by.... 5%

Renewable scenario:

- •Retrofit commercial solar water heating....2 PJ
- •Retrofit passive solar heating technologies, such as advanced performance windows....5 PJ
- •Implement Freecool in Toronto district heating system, assumes operation of 1,000 hours per annum....7 PJ

*A note about plug load: it is the fastest growing component of energy use in commercial buildings. The U.S. Office of Technology Assessment, however, estimates that the energy used by of office equipment may be reduced by 80 percent over the next 15 years if investments in new technology are made, with 65 percent of the savings from new technology (such as the incorporation of laptop computer technologies into desk computers)and a 40 percent reduction in idle time.

ENERGY INTENSITY TARGET FOR NEW BUILDINGS:

It is assumed that the average energy intensity of new buildings declines 50 percent from the average level of the 1988 building stock, as given in Table 1. Hence, office building stock constructed 1988-2005, for example, would average .7 GJ/m² or 18 kWh/ft² in 2005. Furthermore, fuel shares given in Table B-5 are assumed, with solar assuming 30 percent of the space and water heating loads, and electricity declining

from 13 percent (1988) to 5 percent of the space heating share, and from 25 percent (1988) to 10 percent of the water heating share.

The results of the measures on CO_2 emissions spreadsheet analysis are shown for existing buildings in Tables C-7-to-C-10, and for new buildings in Table C-11. As a result of the measures described above, CO_2 emissions are reduced by 46 percent from 1988 levels. The results are summarized in the following table:

Table C-12: Summary of CO_2 Reduction Measures in Commercial Sector

Scenario applied	Total energy use *PJ*	Total CO_2 *Mt*
Base (1988)	188.20	11.93
Scenarios for existing:		
(i) efficiency	152.90	5.61
(ii) fuel switch	152.89	5.51
(iii) renewable	152.89	5.00
New Buildings	52.27	1.50
Total 2005	205.15	6.50

Much of the reduction indicated is due to the decline in electricity's share of building energy—from 58 percent to 53 percent in existing buildings, for instance—keeping electricity demand to a 20 percent rise (while floor space increases by 52 percent), and a lower CO_2 emissions rate for electricity consumed in 2005, which is less than half the emissions rate for 1988. The changes in electricity use and emissions from such use are summarized in Table C-13.

Table C-13: Summary of Changes in Commercial Electricity Use, 1988-2005

	1988 Energy PJ	2005 Energy PJ	1988 CO_2 Mt	2005 CO_2 Mt
Existing buildings	95.04	80.59	8.14	2.01
New buildings	n/a	33.22	n/a	0.07
TOTAL	95.04	113.81	8.14	2.08

Table C-1: Energy Intensity by Category of Building, 1988

	1989 floor area m^2	Annual growth %	1987 floor area m^2	1988 floor area m^2	1988 energy PJ	1988 energy intensity GJ/m^2	1988 energy intensity kWh/ft^2	2005 energy intensity GJ/m^2	2005 energy intensity kWh/ft^2
Education	29	0.83%	28	29	22	0.78	20	0.39	10
Elementary/secondary	20	0.83%	19	20	14	0.73	19	0.37	9
Colleges/universities	9	0.83%	9	9	8	0.89	23	0.44	11
Religious	6	0.50%	6	6	4	0.73	19	0.37	9
Health	8	1.35%	8	8	12	1.50	39	0.75	19
Retail	23	2.90%	22	23	39	1.74	45	0.87	22
Offices	35	3.20%	33	34	49	1.43	37	0.71	18
Public Service	7	2.90%	6	6	6	0.98	25	0.49	13
Accommodations	9	2.90%	9	9	18	2.03	53	1.02	26
Warehouses	30	2.90%	28	29	18	0.61	16	0.31	8
Recreation	5	2.90%	5	5	7	1.47	38	0.74	19
Miscellaneous	8	2.90%	7	7	13	1.72	44	0.86	22
Multi-residential	*78*	*1.97%*	*75*	*76*	*49*	*0.65*	*17*	*0.32*	*8*
Total floor space	159	2.42%	152	155	188	1.21	31	0.60	16

Note: Multi-residential is included as a separate item and is not reflected in totals.
Sources: Ontario Hydro (1989 area and 1988 energy use) and Ministry of Energy (annual growth)

Table C-2: Estimated New Commercial Floor space, 1989-2005

	1988 floor area m^2	2005 floor area m^2	Floor area added 1989-2005 m^2	2005 energy use PJ
Education	28.51	32.81	4.30	1.68
Elementary/secondary	19.50	22.44	2.94	1.08
Colleges/universities	9.01	10.37	1.36	0.60
Religious	5.93	6.45	0.52	0.19
Health	7.73	9.71	1.98	1.49
Retail	22.65	36.83	14.18	12.32
Offices	34.32	58.62	24.31	17.36
Public Service	6.34	10.30	3.96	1.94
Accommodations	8.77	14.26	5.49	5.58
Warehouses	29.18	47.44	18.26	5.60
Recreation	4.71	7.65	2.95	2.17
Miscellaneous	7.31	11.89	4.58	3.94
Multi-residential	*76.42*	*106.38*	*29.96*	*9.70*
Total floor space	155.44	235.96	80.52	52.27

Note: Multi-residential is included as a separate item and is not reflected in totals.

Table C-3: Energy Demand Shares by Function & End Use in Existing Buildings, 1988 (PJ))

	Elec.	Gas	Oil	Total	% Total	% Elec.	% Gas	% Oil
Heating	12.14	74.25	7.23	93.61	100%	13%	79%	8%
Cooling	21.48	1.03	0.00	22.52	100%	95%	5%	0%
Water heating	3.96	11.24	0.82	16.02	100%	25%	70%	5%
Cooking	2.49	3.90	0.00	6.39	100%	39%	61%	0%
Miscel.	13.77	0.76	0.00	14.52	100%	95%	5%	0%

Table C-4: Energy Use in Existing Commercial Buildings, in 1988 (PJ)

	Heating	Cooling	Ventilation	Water heating	Cooking	Refrigeration	External lighting	Internal lighting	Sub-tot. lighting	Plug-load	Misc.	Total
Education	11.43	0.98	1 24	1.38	0.30	0.39	0.47	4.49	4.96	1 15	0 42	22 26
Elementary/secondary	8.15	0.20	0 64	0.82	0.16	0.22	0.30	2.92	3.22	0.71	0.15	14.28
Colleges/universities	3.28	0.78	0.60	0.55	0.14	0.17	0.17	1.57	1.75	0.44	0.26	7.98
Religious	2.70	0.11	0.18	0.19	0.04	0.03	0.09	0.75	0.84	0.12	0.12	4.33
Health	4.90	1.04	0.75	0.78	0.21	0.22	0.15	2.10	2.25	0.49	0.96	11.60
Retail	12.05	4.69	3.46	1.75	1.22	0.82	2.20	7.83	10.03	3.54	1.82	39.37
Offices	12.79	8.88	5.94	0.99	0.26	0.31	1.17	11.72	12.89	5.59	1.38	49.03
Public Service	2.74	0.48	0.38	0.43	0.21	0.04	0.15	1.08	1.23	0.59	0.09	6.19
Accomodations	5.21	2.36	1.49	1.94	1.95	0.18	0.48	2.40	2.89	1.09	0.75	17.85
Warehouses	8.16	0.37	0.40	0.11	0.00	0.46	0.92	4.60	5.52	1.19	1.69	17.90
Recreation	1.75	0.77	0.46	0.47	0.19	0.06	0.37	1.12	1.49	0.39	1.36	6.94
Miscellaneous	4.00	0.94	0.87	0.65	0.27	0.12	1.15	2.16	3.32	0.91	1.51	12.59
Multi-residential	*27.87*	*1.89*	*0.39*	*7.35*	*1.74*	*2.58*	*0.29*	*2.74*	*3.03*	*0.15*	*4.49*	*49.48*
TOTAL	65.75	20.63	15.18	8.68	4.65	2.63	7.15	38.25	45.40	15.05	10.09	188.05

Note: Multi-residential is included as a separate item and is not reflected in totals.

Table C-5: Energy Demand by Function & End Use in New Buildings Constructed 1989-2005, in 2005

	Elec.	Gas	Oil	Solar	Total
Heating	5%	63%	2%	30%	100%
Cooling	95%	5%	0%	0%	100%
Water heating	10%	60%	0%	30%	100%
Cooking	40%	60%	0%	0%	100%
Miscellaneous	95%	5%	0%	0%	100%

Table C-6: Energy Use in New Buildings Constructed 1989-2005, in 2005 (PJ)

	Heating	Cooling	Ventilation	Water heating	Cooking	Refrigeration	Lighting	Plug-load	Misc.	Total
Education	0.86	0.07	0.09	0.10	0.02	0.03	0.37	0.09	0.03	1.68
Elementary/secondary	0.61	0.02	0.05	0.06	0.01	0.02	0.24	0.05	0.01	1.08
Colleges/universities	0.25	0.06	0.05	0.04	0.01	0.01	0.13	0.03	0.02	0.60
Religious	0.12	0.00	0.01	0.01	0.00	0.00	0.04	0.01	0.01	0.19
Health	0.63	0.13	0.10	0.10	0.03	0.03	0.29	0.06	0.12	1.49
Retail	3.77	1.47	1.08	0.55	0.38	0.26	3.14	1.11	0.57	12.32
Offices	4.53	3.15	2.10	0.35	0.09	0.11	4.56	1.98	0.49	17.36
Public Service	0.86	0.15	0.12	0.14	0.07	0.01	0.39	0.18	0.03	1.94
Accomodations	1.63	0.74	0.47	0.61	0.61	0.06	0.90	0.34	0.23	5.58
Warehouses	2.55	0.12	0.13	0.03	0.00	0.14	1.73	0.37	0.53	5.60
Recreation	0.55	0.24	0.15	0.15	0.06	0.02	0.47	0.12	0.42	2.17
Miscellaneous	1.25	0.29	0.27	0.20	0.09	0.04	1.04	0.28	0.47	3.94
Multi-residential	*5.46*	*0.37*	*0.08*	*1.44*	*0.34*	*0.51*	*0.60*	*0.03*	*0.88*	*9.70*
TOTAL	22.21	6.74	4.59	3.67	1.68	1.20	13.51	4.57	3.79	52.27

***Note**: Multi-residential is included as a separate item and is not reflected in totals.*

Table C-7: CO_2 Emissions from Existing Commercial Buildings, in 1988

	Space heating	Water heating	Space cooling	Cooking	Venti-lation	Refrig-eration	Lighting	Plug-load	Misc.	Total
Education	0.63	0.07	0.07	0.02	0.09	0.03	0.35	0.08	0.03	1.36
Elementary/secondary	0.45	0.04	0.01	0.01	0.04	0.02	0.22	0.05	0.01	0.86
Colleges/universities	0.18	0.03	0.05	0.01	0.04	0.01	0.12	0.03	0.02	0.50
Religious	0.15	0.01	0.01	0.00	0.01	0.00	0.06	0.01	0.01	0.26
Health	0.25	0.04	0.07	0.01	0.05	0.02	0.16	0.03	0.07	0.70
Retail	0.67	0.10	0.32	0.07	0.24	0.06	0.70	0.25	0.13	2.54
Offices	0.70	0.06	0.61	0.01	0.42	0.02	0.90	0.39	0.10	3.21
Public Service	0.15	0.02	0.03	0.01	0.03	0.00	0.09	0.04	0.01	0.38
Accomodations	0.28	0.11	0.16	0.11	0.10	0.01	0.20	0.08	0.05	1.11
Warehouses	0.42	0.01	0.03	0.00	0.03	0.03	0.39	0.08	0.12	1.10
Recreation	0.10	0.03	0.05	0.01	0.03	0.00	0.10	0.03	0.09	0.45
Miscellaneous	0.24	0.03	0.06	0.02	0.06	0.01	0.23	0.06	0.11	0.83
Multi-residential	1.54	0.42	0.13	0.12	0.03	0.18	0.21	0.01	0.31	2.95
TOTAL	3.59	0.48	1.42	0.27	1.06	0.18	3.17	1.05	0.71	**11.93**

Table C-8: CO_2 Emissions from Existing Commercial Buildings (Efficiency scenario), in 2005

	Space heating	Water heating	Space cooling	Cooking	Venti-lation	Refrig-eration	Lighting	Plug-load	Misc.	Total
Education	0.54	0.05	0.02	0.01	0.03	0.01	0.07	0.02	0.01	0.76
Elementary/secondary	0.38	0.03	0.00	0.01	0.01	0.01	0.04	0.01	0.00	0.51
Colleges/universities	0.15	0.02	0.02	0.01	0.01	0.00	0.02	0.01	0.01	0.26
Religious	0.13	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.17
Health	0.22	0.03	0.02	0.01	0.02	0.01	0.03	0.01	0.02	0.38
Retail	0.51	0.07	0.11	0.05	0.08	0.02	0.14	0.07	0.05	1.08
Offices	0.61	0.04	0.21	0.01	0.13	0.01	0.17	0.11	0.03	1.33
Public Service	0.12	0.02	0.01	0.01	0.01	0.00	0.02	0.01	0.00	0.20
Accomodations	0.23	0.08	0.06	0.08	0.03	0.00	0.04	0.02	0.02	0.55
Warehouses	0.37	0.00	0.01	0.00	0.01	0.01	0.07	0.02	0.04	0.54
Recreation	0.08	0.02	0.02	0.01	0.01	0.00	0.02	0.01	0.03	0.20
Miscellaneous	0.21	0.03	0.02	0.01	0.02	0.00	0.04	0.02	0.04	0.40
Multi-residential	1.14	0.27	0.04	0.01	0.01	0.02	0.04	0.00	0.03	1.57
TOTAL	3.03	0.35	0.48	0.19	0.33	0.07	0.62	0.30	0.25	**5.61**

Table C-9: CO2 Emissions from Existing Commercial Buildings (Fuel switch scenario), 2005

	Space heating	Water heating	Space cooling	Cooking	Ventilation	Refrigeration	Lighting	Plug-load	Misc.	Total
Education	0.52	0.05	0.02	0.01	0.03	0.01	0.07	0.02	0.01	0.74
Elementary/secondary	0.37	0.03	0.00	0.01	0.01	0.01	0.04	0.01	0.00	0.49
Colleges/universities	0.15	0.02	0.02	0.01	0.01	0.00	0.02	0.01	0.01	0.25
Religious	0.13	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.16
Health	0.22	0.03	0.02	0.01	0.02	0.01	0.03	0.01	0.02	0.37
Retail	0.50	0.07	0.11	0.05	0.08	0.02	0.14	0.07	0.05	1.07
Offices	0.58	0.04	0.21	0.01	0.13	0.01	0.17	0.11	0.03	1.30
Public Service	0.12	0.02	0.01	0.01	0.01	0.00	0.02	0.01	0.00	0.20
Accomodations	0.23	0.08	0.06	0.08	0.03	0.00	0.04	0.02	0.02	0.55
Warehouses	0.37	0.00	0.01	0.00	0.01	0.01	0.07	0.02	0.04	0.54
Recreation	0.08	0.02	0.02	0.01	0.01	0.00	0.02	0.01	0.03	0.20
Miscellaneous	0.20	0.03	0.02	0.01	0.02	0.00	0.04	0.02	0.04	0.38
Multi residential	1.13	0.27	0.04	0.01	0.01	0.02	0.04	0.00	0.03	1.56
TOTAL	2.93	0.34	0.48	0.19	0.33	0.07	0.62	0.30	0.25	5.51

Table C-10: CO2 Emissions from Existing Commercial Buildings (Renewable scenario), 2005

	Space heating	Water heating	Space cooling	Cooking	Ventilation	Refrigeration	Lighting	Plug-load	Misc.	Total
Education	0.47	0.04	0.02	0.01	0.03	0.01	0.07	0.02	0.01	0.68
Elementary/secondary	0.34	0.02	0.00	0.01	0.01	0.01	0.04	0.01	0.00	0.45
Colleges/universities	0.14	0.02	0.01	0.01	0.01	0.00	0.02	0.01	0.01	0.23
Religious	0.12	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.15
Health	0.20	0.03	0.02	0.01	0.02	0.01	0.03	0.01	0.02	0.34
Retail	0.46	0.05	0.07	0.05	0.08	0.02	0.14	0.07	0.05	0.97
Offices	0.53	0.03	0.14	0.01	0.13	0.01	0.17	0.11	0.03	1.17
Public Service	0.11	0.01	0.01	0.01	0.01	0.00	0.02	0.01	0.00	0.18
Accomodations	0.21	0.06	0.04	0.08	0.03	0.00	0.04	0.02	0.02	0.49
Warehouses	0.33	0.00	0.01	0.00	0.01	0.01	0.07	0.02	0.04	0.50
Recreation	0.07	0.01	0.01	0.01	0.01	0.00	0.02	0.01	0.03	0.18
Miscellaneous	0.18	0.02	0.01	0.01	0.02	0.00	0.04	0.02	0.04	0.35
Multi-residential	1.04	0.20	0.03	0.01	0.01	0.02	0.04	0.00	0.03	1.38
TOTAL	2.68	0.25	0.32	0.19	0.33	0.07	0.62	0.30	0.25	5.00

Table C-11: CO_2 Emissions New Buildings Built 1989-2005, 2005 (MT)

	Heating	Cooling	Ventilation	Water heating	Cooking	Refrigeration	Lighting	Plug-load	Misc.	Total
Education	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.05
Elementary/secondary	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.03
Colleges/universities	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Religious	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Health	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.04
Retail	0.13	0.04	0.03	0.02	0.02	0.01	0.08	0.03	0.01	0.35
Offices	0.15	0.08	0.05	0.01	0.00	0.00	0.11	0.05	0.01	0.48
Public Service	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.06
Accomodations	0.06	0.02	0.01	0.02	0.02	0.00	0.02	0.01	0.01	0.17
Warehouses	0.09	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.01	0.16
Recreation	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.06
Miscellaneous	0.04	0.01	0.01	0.01	0.00	0.00	0.03	0.01	0.01	0.11
Multi-residential	*0.19*	*0.01*	*0.00*	*0.05*	*0.01*	*0.01*	*0.01*	*0.00*	*0.02*	*0.31*
TOTAL	0.75	0.18	0.11	0.12	0.07	0.03	0.34	0.11	0.09	1.80

Steel industry forecasts assume a 2.1 percent annual increase in natural gas and oil, a 20 percent total increase in coal and an 80 percent total increase in electricity (before efficiency measures). One of the primary difficulties in outlining a strategy for achieving a 20 percent reduction of 1988 level CO_2 emissions in 2005, is that the forecasted emissions, due to the high projected rate of economic growth, appear to outweigh the opportunities for efficiency gains. Projecting economic growth in the 1990s based on the experience of the late 1980's has resulted in overstated growth in 1990 and 1991. The GDP for Canada fell 0.9 percent in 1990, was -4.0 percent for the three month period ending February 28, 1991 and is expected to be -1 percent in 1991. Since so much of the 20 percent target is contingent upon forecasted industrial output, it is important to consider the role of economic forecasting as it relates to CO_2 production and energy demand. Different assumptions at the beginning of an economic forecast period may result in radically diverging forecasts, the further the forecast is projected. The Ministry of Energy is assuming an annual growth rate in industrial energy demand of 2.6 percent and an annual increase in GDP of 3 percent. The 2.1 percent average annual increase in energy demand for the industrial sector is based on the average annual energy increase form 1970 to 1989.

Efficiency assumptions take into consideration only the percentage of measures deemed to be economically implementable. In addition to strict quantifiable analysis, there are opportunities for increasing implementation rates when combined with the policy measures described in the report. For example, increased electricity prices relative to gas prices, incentives for companies to install cogeneration and education programmes all serve to increase penetration of cogeneration technology, however, the effects of the measures are difficult to quantify in the analysis.

Distinguishing an efficiency improvement factor—energy conservation that occurs "naturally" in response to prices and to available incentives—is more difficult to do in the industrial sector, where growth often results from increased utilization of existing capacity. In other sectors, the energy characteristics of new units of housing, office buildings, or passenger cars can be identified and enumerated more easily. Such a sophisticated analysis was beyond the scope of this effort. Our simplified assumption that energy demand growth in the industrial sector will approximate the historic trend, therefore, assumes some imbedded energy conservation. As a result, care should be taken in reviewing the efficiency measures presented in the industrial sector, as there is no doubt some "double-counting" among the specific measures discussed, such as installation of energy efficient motors, and the conservation embedded in future growth.

The following assumptions were used in the spreadsheet analysis:

Energy Growth to 2005:

- 2.1% per annum (42% total increase) for all industries with specific variations in fuel type for steel (42% increase in oil and gas, 20% increase in coal and 80% increase in electricity).

Fuel Shares—All Industries except steel

- The share of Heat from oil and natural gas is 90%
- The share of Other end uses from oil and natural gas is........................ 10%
- The share of Heat from coal and wood i 90%
- The share of Other end uses from coal and wood is............................ 10%

Chemicals

- The share of Motive power from electricity is..80%
- The share of Other end uses from electricity is.......................................13%
- The share of Lighting from electricity is 7%

Iron and Steel

- The share of Heat from oil and natural gas is 87%
- The share of Other end uses from oil and natural gas is.........................13%
- The share of Heat from coal is 87%
- The share of Other end uses from coal is 13%
- The share of Motive power from electricity is..76%
- The share of Other end uses from electricity is.......................................16%
- The share of Lighting from electricity is 8%

Cement and Other

- The share of Motive power from electricity is..76%
- The share of Other end uses from electricity is.......................................16%
- The share of Lighting from electricity is 8%

Pulp and Paper

- The share of Motive power from electricity is..95%
- The share of Other end uses from electricity is.......................................0%
- The share of Lighting from electricity is 5%

Efficiency Assumptions

- Increased use of heat recovery reduces all non-coal heat by 25% at 70% penetration total savings is.. 17.5%
- Heat recovery in steel industry is further developed, therefore remaining savings in steel industry is estimated to be 10%
- All motive power improvements (high efficiency motors, variable drives, proper sizing, etc) improve efficiency by 20% with a 70% penetration rate resulting in a total motive energy reduction of 14%
- Housekeeping measures, including insulation, process changes PINCH Technology and general efficiency awareness can provide a savings of 10%-40%. For the analysis the most conservative estimate is used with a penetration rate of 70%, therefore the savings applied to all energy is 7%
- A 65% improvement in lighting efficiency is assumed with a 70% penetration rate, resulting in a total savings in lighting energy of........ 45.5%
- A combination of heat recovery and fuel substitution (heat from waste) results in a savings of coal use in the cement industry, assuming 70% penetration of.................................. 10.5%

Fuel Switching Assumptions

N.B. COGENERATION ASSUMPTIONS ARE CONTAINED IN ELECTRICITY ANALYSIS, NOT INDUSTRIAL ANALYSIS.

- The use of steam and gas turbine cogeneration to produce electricity and heat can provide 65 PJ of industrial electricity using the economic potential of the Acres report. This would result in an increase in natural gas consumption in the chemicals sub-sector of......................... 45% and an average increase in natural gas across all other sectors of.............. 20% with the exception of pulp and paper where wood waste is

used for steam turbine cogeneration.

- Cogeneration creates a savings in utility-produced electricity of 35%
- Increased use of coal injection will reduce CO_2 in the steel industry by....... 5%

Renewable Resource Assumptions

- By implementing sustainable forestry management practices it is assumed that all CO_2 emitted from the burning of wood and wood waste can be offset, resulting in a reduction in wood waste CO_2 of 100 percent.This assumes that the wood-related CO_2 emissions from this industry in 1988 reported by the Ministry of Energy derived from unsustainable forestry management practices. Some natural regeneration and silviculture does presently take place, of course, so the reduction from this measure is somewhat overstated. Given the lack of data on biomass regeneration, however, we adopted the simplifying assumption.

Iron and Steel Industry

With respect to the iron and steel industry, the forecasted energy demand is projected to be 333 PJ in 2005, before additional conservation measures are applied (a 30 percent increase as opposed to a 50 percent increase.) This assumption is based on the general economic outlook for Ontario's steel industry, including; a longer than expected turnaround time for the economy, increasing foreign imports, increased substitution and generally a more bearish projection for demand of Ontario steel. Information in Table 1e is computed using data directly from Table 2d, therefore numbers between Tables 1d and 1e do not correlate for the steel industry.

Notes on Coke Oven Gas Emissions

- It takes one tonne of coal to produce .75 tonne of coke.
- 340 m^3 of coke oven gas are produced for every tonne of coal burned.
- 0.4 m^3 of CO_2 is formed for every 1 m3 of coke oven gas burned.
- 100 percent of coke oven gas is burned.
- Approximately 5,500,000 tonnes of coal were burned to make coke in Ontario in 1988.
- Therefore, 1.87 trillion m^3 of coke oven gas was created and 748 million m^3 of CO_2 were formed by coke ovens in Ontario.

  Assuming 50 kg CO_2 /GJ for coke oven gas and .01816 GJ/m^3 coke oven gas, therefore: 0.9 kg CO_2 /m3 or .0009 tonnes/m3 x 748 million m^3 = 673 kilotonnes of CO_2 (4% of steel industry CO_2)
- 26 percent of coke oven gas is methane, a much more potent global warming gas.

****

CALCULATIONS OF ENERGY CONSUMPTION AND CO2 EMISSIONS FOR INDUSTRIAL SECTOR IN ONTARIO

****

Energy Growth Rates	1989-90	1991-95	1996-00	2001-05	Total
Iron and Steel	Average growth of 2.1% (See Below).				1.42
Pulp/paper	2.10	2.10	2.10	2.10	1.42
Chemical	2.10	2.10	2.10	2.10	1.42
Cement	2.10	2.10	2.10	2.10	1.42
Other	2.10	2.10	2.10	2.10	1.42

Iron and Steel (by 2005, oil and gas increase 42%, coal increases 20% and electricity use increases by 80%).

Table 1a 1988 Base Energy Consumption Weather Corrected Actuals (Petajoules)

	Oil	NatGas/NGL	Coal	Wood	Subtotal	Elect'y	Total	
INDUSTRY								
Chemicals	13.60	38.60			52.20	24.70	76.90	
Heat					0.00		0.00	
Motive					0.00		0.00	
Other					0.00		0.00	
Lights					0.00		0.00	
Iron/Steel	15.30	46.30	168.70		230.30	23.20	253.50	
Heat					0.00		0.00	
Motive					0.00		0.00	
Other					0.00		0.00	
Lights					0.00		0.00	
Cement	4.20	1.80	19.50		25.50	2.90	28.40	
Heat					0.00		0.00	
Motive					0.00		0.00	
Other					0.00		0.00	
Lights					0.00		0.00	
Pulp/Paper	7.00	41.10	1.80	72.20	122.10	28.70	150.80	
Heat					0.00		0.00	
Motive					0.00		0.00	
Other					0.00		0.00	
Lights					0.00		0.00	
Other	54.20	256.40	14.20	0.00	324.80	90.70	415.50	
Heat					0.00		0.00	
Motive					0.00		0.00	
Other					0.00		0.00	
Lights					0.00		0.00	
Total	94.30	384.20	204.20	72.20	754.90	170.20	925.10	0.0

Table 1c 2005 Energy Consumption Projections with End Uses (Petajoules)

	Oil	NatGas/NGL	Coal	Wood	Subtotal	Elect'y	Total	Ministry
INDUSTRY								
Chemicals(total)	19.31	54.81			74.12	35.07	109.20	128.90
Heat	17.38	49.33			66.71		66.71	
Motive					0.00	4.56	4.56	
Other	1.93	5.48			7.41	28.06	35.47	
Lights					0.00	2.46	2.46	
Iron/Steel(total)	21.73	65.75	202.44		289.91	41.76	331.67	423.70
Heat	18.90	57.20	176.12		252.22		252.22	
Motive					0.00	31.74	31.74	
Other	2.82	8.55	26.32		37.69	6.68	44.37	
Lights					0.00	3.34	3.34	
Cement(total)	5.98	2.56	27.76		36.31	4.13	40.43	58.70
Heat	5.38	2.31	24.99		32.68		32.68	
Motive					0.00	3.34	3.34	
Other	0.60	0.26	2.78		3.63	0.41	4.04	
Lights					0.00	0.37	0.37	
Pulp/Paper(total)	9.97	58.52	2.56	102.80	173.84	40.86	214.70	217.30
Heat	8.97	52.66	2.31	92.52	156.46		156.46	
Motive					0.00	38.82	38.82	
Other	1.00	5.85	0.26	10.28	17.38		17.38	
Lights					0.00	2.04	2.04	
Other(total)	77.17	365.05	20.22	0.00	462.44	129.14	591.57	556.20
Heat	69.45	328.55	18.20		416.19		416.19	
Motive					0.00	104.60	104.60	
Other	7.72	36.51	2.02		46.24	12.91	59.16	
Lights					0.00	11.62	11.62	
Total	134.15	546.69	252.98	102.80	1036.62	250.96	1287.58	1384.80

Assumptions:

Fossil fuels are 90% heat and 10% other.

Electricity is 76% motive, 16% other and 8% lights except for:

Chemicals which is 80% other (electrolysis), 13% motive and 7% lights.

Pulp and Paper which is 95% motive and 5% lights.

Table 1d 2005 Energy Consumption Projections with Efficiency Measures (Petajoules)

	Oil	NatGas/NGL	Coal	Wood	Subtotal	Elect'y	Total	Ministry
INDUSTRY								
Chemicals								128.90
Heat	13.34	37.85			51.18		51.18	
Motive					0.00	3.92	3.92	
Other	1.80	5.10			6.89	26.10	32.99	
Lights					0.00	1.34	1.34	
Total	15.13	42.95	0.00	0.00	58.08	31.35	89.43	
Iron/Steel								423.70
Heat	15.00	45.40	169.44		229.84		229.84	
Motive					0.00	27.29	27.29	
Other	2.02	6.11	18.83		26.96	6.21	33.18	
Lights					0.00	1.82	1.82	
Total	17.02	51.51	188.27	0.00	256.81	35.33	292.13	
Cement								58.70
Heat	4.13	1.77	20.80		26.70		26.70	
Motive					0.00	2.70	2.70	
Other	0.56	0.24	2.58		3.38	0.61	3.99	
Lights					0.00	0.18	0.18	
Total	4.69	2.01	23.38	0.00	30.07	3.49	33.57	
Pulp/Paper								217.30
Heat	6.88	40.41	2.15	86.04	135.47		135.47	
Motive					0.00	33.38	33.38	
Other	0.93	5.44	0.24	9.56	16.17		16.17	
Lights					0.00	1.11	1.11	
Total	7.81	45.85	2.38	95.60		34.50	34.50	
Other								556.20
Heat	53.29	252.08	16.92		322.29		322.29	
Motive					0.00	84.40	84.40	
Other	7.18	33.95	1.88		43.01	19.22	62.22	
Lights					0.00	5.63	5.63	
Total	60.46	286.03	18.80	0.00	365.29	109.25	474.54	
Total	105.11	428.35	232.83	95.60	710.25	213.92	924.17	1384.80

Assumptions:

Efficiency Improvements		Penetration Rate	Net Improvement
Heat recovery (25% reduction of all non-coal heat)	0.83	70%	17%
Motive Power (20% improvement)	0.86	70%	14%
House Keeping (10% reduction on everything)	0.93	70%	7%
Lighting (65% reduction in lighting)	0.55	70%	46%
Cement (25% coal reduction -heat recovery and fuel sub.)	0.90	70%	11%

Table 1e 2005 Energy Consumption Projections with Added Fuel Switching (Petajoules)

	Oil	NatGas/NGL	Coal	Wood	Subtotal	Elect'y	Total	Ministry
DUSTRY								
Chemicals								128.90
Heat	13.34	37.85			51.18		51.18	
Motive					0.00	3.92	3.92	
Other	1.80	5.10			6.89	26.10	32.99	
Lights					0.00	1.34	1.34	
Total	15.13	42.95	0.00	0.00	58.08	31.35	89.43	
Iron/Steel								423.70
Heat	15.00	45.40	160.97		221.37		221.37	
Motive					0.00	27.29	27.29	
Other	2.02	6.11	17.89		26.02	6.21	32.23	
Lights					0.00	1.82	1.82	
Total	17.02	51.51	178.86	0.00	247.39	35.33	282.72	
Cement								58.70
Heat	4.13	1.77	20.80		26.70		26.70	
Motive					0.00	2.70	2.70	
Other	0.56	0.24	2.58		3.38	0.61	3.99	
Lights					0.00	0.18	0.18	
Total	4.69	2.01	23.38	0.00	30.07	3.49	33.57	
Pulp/Paper								217.30
Heat	6.88	40.41	2.15	86.04	135.47		135.47	
Motive					0.00	33.38	33.38	
Other	0.93	5.44	0.24	9.56	16.17	0.00	16.17	
Lights					0.00	1.11	1.11	
Total	7.81	45.85	2.38	95.60		34.50	186.14	
Other								556.20
Heat	53.29	252.08	16.92		322.29		322.29	
Motive					0.00	84.40	84.40	
Other	7.18	33.95	1.88		43.01	19.22	62.22	
Lights					0.00	5.63	5.63	
Total	60.46	286.03	18.80	0.00	365.29	109.25	474.54	
Total	105.11	428.35	223.42	95.60	700.84	213.92	1066.40	1384.80

sumptions: N.B. COGENERATION IS INCLUDED IN ELECTRICITY SECTION, NOT INDUSTRIAL, THEREFORE NO EFFECTS ASSUMED.
uel Switching is based on Acres Report of 65 PJ of current economic potential
n the industrial sector, 35 percent of 1988 electricity (27% of 2005 Forecast Demand).
ost cogen. in paper and chemicals, therefore lower percent increase in gas in other industries.

Cogeneration (wood waste used for cogen. in pulp and paper)	1.00
(45% increase in natural gas heat in chemicals)	1.00
(20% average increase in gas heat in other industries)	1.00
(27% reduction in electricity)	1.00
Coal Injection in Steel Industry (5% reduction in coal-based CO2)	0.95

Table 1f 2005 Energy Consumption Projections with Renewable Energy (Petajoules)

	Oil	NatGas/NGL	Coal	Wood	Subtotal	Elect'y	Total	Ministry
INDUSTRY								
Chemicals								128.90
Heat	13.34	37.85			51.18		51.18	
Motive					0.00	3.92	3.92	
Other	1.80	5.10			6.89	26.10	32.99	
Lights					0.00	1.34	1.34	
Total	15.13	42.95	0.00	0.00	58.08	31.35	89.43	
Iron/Steel								423.70
Heat	15.00	45.40	160.97		221.37		221.37	
Motive					0.00	27.29	27.29	
Other	2.02	6.11	17.89		26.02	6.21	32.23	
Lights					0.00	1.82	1.82	
Total	17.02	51.51	178.86	0.00	247.39	35.33	282.72	
Cement								58.70
Heat	4.13	1.77	20.80		26.70		26.70	
Motive					0.00	2.70	2.70	
Other	0.56	0.24	2.58		3.38	0.61	3.99	
Lights					0.00	0.18	0.18	
Total	4.69	2.01	23.38	0.00	30.07	3.49	33.57	
Pulp/Paper								217.30
Heat	6.88	40.41	2.15	0.00	49.43		49.43	
Motive					0.00	33.38	33.38	
Other	0.93	5.44	0.24	0.00	6.61	0.00	6.61	
Lights					0.00	1.11	1.11	
Total	7.81	45.85	2.38	0.00		34.50	90.54	
Other								556.20
Heat	53.29	252.08	16.92		322.29		322.29	
Motive					0.00	84.40	84.40	
Other	7.18	33.95	1.88		43.01	19.22	62.22	
Lights					0.00	5.63	5.63	
Total	60.46	286.03	18.80	0.00	365.29	109.25	474.54	
Total	105.11	428.35	223.42	0.00	700.84	213.92	970.80	1384.80

Assumptions:
Renewable Resources
Sustainable forestry practices are adopted so
that all wood waste emissions are offset through reforestation.

ole 1g 2005 CO2 Projections (Kilotonnes)

	Oil	atGas/NGL	Coal	Wood	Subtotal	Elect'y	Total	1988
)USTRY								
:hemicals	19.31	54.81			74.12	35.07	109.20	
Heat	981.49	1881.10			2862.58		2862.58	
Motive					0.00	97.57	97.57	
Other	132.19	253.35			385.53	649.34	1034.87	
Lights					0.00	33.30	33.30	
otal	1113.67	2134.44	0.00	0.00	3248.12	780.21	4028.32	4624.00
on Steel	21.78	65.92	214.88		302.59	33.03	335.62	
Heat	1104.17	2256.34	14326.34		17686.86		17686.86	
Motive					0.00	679.18	679.18	
Other	148.71	303.88	1591.82		2044.41	154.62	2199.03	
Lights					0.00	45.31	45.31	
ota	1252.88	2560.23	15918.16	0.00	19731.27	879.11	20610.38	20034.00
ement	5.98	2.56	27.76		36.31	4.13	40.43	
Heat	303.91	87.95	1851.02		2242.88		2242.88	
Motive					0.00	67.15	67.15	
Other	40.93	11.85	49.49		102.27	15.29	117.56	
Lights					0.00	4.48	4.48	
otal	344.84	99.80	1900.51	0.00	2345.15	86.92	2432.07	2333.00
ulp Paper	9.97	58.52	2.56	102.80	173.84	40.86	214.70	
Heat	506.52	2008.24	190.91	0.00	2705.66		2705.66	
Motive					0.00	830.72	830.72	
Other	68.22	270.47	21.21	0.00	359.90	0.00	359.90	
Lights					0.00	27.71	27.71	
otal	574.73	2278.71	212.12	0.00	3065.56	858.42	3923.99	11914.00
ther	77.17	365.05	20.22	0.00	462.44	129.14	591.57	
Heat	3921.88	12528.28	1506.06		17956.21		17956.21	
Motive					0.00	2100.24	2100.24	
Other	528.20	1687.31	167.34		2382.85	478.14	2860.99	
Lights					0.00	140.10	140.10	
otal	4450.08	14215.59	1673.40	0.00	20339.06	2718.48	23057.54	24402.00
otal	7736.21	21288.77	19704.19	0.00	48729.17	5323.14	54052.30	63307.00

ilotonne CO2 per PJ	
)il	73.60
ias	49.70
oal	89.00
lec	24.88347
Vood	100.00

ROJECTED CO2 54052 Kilotonnes
88 ACTUAL CO: 63307 Kilotonnes

ET CHANGE = -14.6%

Table 2 Industrial Electricity Demand Forecast

	Utility	Cogen	Total	% Change from 1988
1988 Actual	140.20	30.00	170.20	
2005 Ministry Forecast	254.30	45.40	299.70	76%
2005 At 2.1% Growth, no	199.08	42.60	241.68	42%
2005 with Efficiency Me	213.92	65.00	278.92	64%

APPENDIX E—TRANSPORTATION SECTOR

Economically achievable CO_2 emissions reductions from passenger automobile use were computed using the Ministry of Energy's projections for growth in passenger vehicles and distance travelled, but modified to include more aggressive assumptions about fuel economy and substitution of natural gas and ethanol for gasoline and diesel fuel. In addition, a 15 percent modal shift from autos to public transit in the Greater Toronto Area (GTA) was simulated using data from the Transportation Tomorrow Survey, *Travel Survey Summary for the Greater Toronto Area*, University of Toronto (June 1989), modified in a spreadsheet with travel growth projections from the Metro Planning Department. Information about TTC vehicle and passenger travel, as well as energy use, was obtained from the TTC.

The economically achievable measured assumed to reduce CO_2 emissions from passenger vehicles include the following:

FUEL ECONOMY OF TRANSPORTATION:
•By 2005 average on-road auto stock efficiency improves from 11.39 L/100 km in 1988 to ....6.7 L/100 km
•By 1994 gas guzzler/sipper rebate programme (DRIVE+) aims to achieve average new car provincial fleet economy of....................5.8 L/100 km
•In 2000-2005 the gas guzzler/sipper rebate programme aims to achieve annual improvement in new car provincial average fuel economy of ....5-6% p.a.
•Provincial and Metro policies encourage significant investment and expansion in public transit to achieve by 2005 modal shift from autos to public transit in GTA of.................................15%
SWITCHING TO NATURAL GAS:
•Policies encourage strong initiative by gas industry and utilities and auto industry to encourage natural gas vehicles, aiming by 2005 at percentage of passenger cars fueled of......................................10%
RENEWABLE FUEL:
•Policies aim to encourage use of ethanol blend for auto fleet, aiming by 2005 at percentage of gasoline passenger cars fueled of...10%
•R&D aims to commercialize production of ethanol from lignocellulose so that no net CO_2 emissions occur from its use by............the year 2005

With respect to the GTA modal shift simulation, the following assumptions were made in the spreadsheet analysis:

- *Load factor*—no change in load factor occur, remaining at 1.468 (urban) and 1.657 (average) in 2005;
- *Average trip length*—annual average kilometres travelled per vehicle declines by .2 percent annually, per the Ministry of Energy's assumptions, and is reflected in a similar decline in average trip length;
- *Modal split*—by 2005 the modal share of automobile travel declines from 72 percent to 57 percent in the GTA, due to land use reforms and a significant expansion in public transit. Public transit ridership increases by 4.1 billion passenger-kilometres, approximately equivalent to the TTC's total ridership in 1988, leading to a six percent decline in total vehicle kilometres travelled in 2005 from the base projection (See Tables E-1-to-E-2)

The results of the spreadsheet analysis are shown in Tables E-3 and E-4; they are divided into three scenarios: an efficiency scenario that includes fuel economy improvements and the modal switch to public transit in the GTA; a fuel substitution scenario that switches 10 percent of passenger cars to natural gas; a renewable scenario that assumes the ethanol blend.

Table E-5 summarizes the estimates, which project a total 33 percent reduction in CO_2 emissions from 1988 levels for passenger vehicle use by 2005.

Table E-5: Summary of CO_2 Reduction Measures

Year	Measure applied	Energy use *PJ*	CO_2 *Mt*	CO_2 change *Mt*	CO_2 increment *Mt*	% change *from 1988*
	Ministry of Energy:					
1988	Base	295	20.0	—	—	—
2005	Projection	366	24.9	+4.9	+4.9	+25%
	Scenarios:					
2005	(i) Fuel economy	237	16.1	-3.9	-3.9	-20%
2005	plus 15% modal shift	223	15.2	-4.8	-0.9	-24%
2005	(ii) Fuel switch (natural gas)	223	14.8	-5.2	-0.4	-26%
2005	(iii) Renewable (ethanol)	223	13.5	-6.5	-1.3	-33%

In order to accurately estimate total CO_2 emissions from the measures described, it is necessary to take into account passengers from automobiles shifted to public transit. In order to make such an estimate, data from the TTC was collected and analyzed to determine emissions. For sake of simplicity, it is assumed the operation of the TTC would have to double to accommodate these new passengers (in fact the TTC does not operate in the outlying GTA areas). In 1988, TTC's total emissions were about .24 Mt (see Table E-6). If these emissions were to double, then total net CO_2 emissions from personal travel would be about 13.75 Mt, a reduction of 31 percent from 1988 levels.

In sum, the modal shift of 15 percent from autos to public transit in the GTA reduces passenger auto travelled by about 4.1 billion kilometres. The reduction in emissions of 1.1 Mt CO_2 is partially offset by an increase in public transit emissions of about .24 Mt, reflecting the fact that automobile travel (in 2005) is 4-to-5 times more carbon intensive per passenger kilometre when compared with public transit (in 1988).

Table E-6: Estimate of TTC CO_2 Emissions, 1988

Vehicle	Total VKT km	Energy use PJ	CO_2 emissions Mt	Energy intensity PJ/ pass-km	CO_2 intensity Mt/ pass-km
Diesel buses	100,117,000	2.2	0.17	1.29	99
Trolley buses	5,281,000	0.05	0.00	0.40	28
Streetcars	13,866,000	0.15	0.01	0.31	22
Subway	72,209,000	0.73	0.05	0.49	35
SRT	2,343,000	0.03	0.00	1.33	93
TOTAL	193,816,000	3.16	0.24	0.83	62

Table E-1: Estimate of GTA Vehicle Kilometres Travelled (weekdays)

	1988	2005 (base)	2005 (modal)
Metro	17.1	15.1	11.1
Durham	4.7	5.4	4.0
York	5.0	7.4	5.5
Peel	7.0	9.7	7.2
Halton	4.0	4.9	3.6
Hamilton	4.2	4.8	3.5
Total Daily VKT (millions)	41.9	47.2	35.0
Total VKT (billions)	**10.9**	**12.3**	**9.1**

Table E-2: Vehicle Mileage Forecast

	Total VKT	GTA VKT only
1988	74,280,000,000	10,902,000000
2005 (base)	102,430,000,000	12,272,000,000
2005 (modal)	96,488,000,000	9,089,000,000

Table E-3: Energy Use by Passenger Vehicles, 1988-2005

	Total	Diesel	Gas	NGLs	Natural gas	Ethanol
1988						
Inter-city	99.00	0.70	98.30	0.00	0.00	0.00
Urban	196.10	1.20	186.40	8.10	0.40	0.00
TOTAL	295.10	1.90	284.70	8.10	0.40	0.00
2005, Base projection						
Inter-city	122.90	5.6	117.3	0	0	0
Urban	242.90	9.1	222.1	8.2	3.5	0
TOTAL	365.80	14.70	339.40	8.20	3.50	0.00
2005, Fuel economy and GTA modal shift						
Inter-city	74.94	3.41	71.53	0.00	0.00	0.00
Urban	148.12	5.55	135.43	5.00	2.13	0.00
TOTAL	223.06	8.96	206.96	5.00	2.13	0.00
2005, Natural gas fuel substitution						
Inter-city	74.94	3.07	64.38	0.00	7.49	0.00
Urban	148.12	4.99	121.89	5.00	16.23	0.00
TOTAL	223.06	8.07	186.27	5.00	23.73	0.00
2005, Conversion to ethanol blend						
Inter-city	74.94	3.07	57.94	0.00	7.49	6.44
Urban	148.12	4.99	109.70	5.00	16.23	12.19
TOTAL	223.06	8.07	167.64	5.00	23.73	18.63

Table E-4: CO2 Emissions from Passenger Vehicle Use, 1988-2005

	Total	Diesel	Gas	NGLs	Natural gas	Ethanol
1988						0
Inter-city	6.74	0.05	6.68	0.00	0.00	0.00
Urban	13.27	0.09	12.67	0.48	0.02	
TOTAL	20.00	0.15	19.35	0.48	0.02	0.00
2005, Base projection						
Inter-city	8.40	0.43	7.97	0.00	0.00	0.00
Urban	16.46	0.70	15.10	0.49	0.17	0.00
TOTAL	24.87	1.13	23.07	0.49	0.17	0.00
2005, Fuel economy and GTA modal shift						
Inter-city	5.13	0.26	4.86	0.00	0.00	0.00
Urban	10.04	0.43	9.21	0.30	0.11	0.00
TOTAL	15.16	0.69	14.07	0.30	0.11	0.00
2005, Natural gas fuel substitution						
Inter-city	4.98	0.24	4.38	0.00	0.37	0.00
Urban	9.77	0.38	8.29	0.30	0.80	0.00
TOTAL	14.76	0.62	12.66	0.30	1.17	0.00
2005, Conversion to ethanol blend						
Inter-city	4.55	0.24	3.94	0.00	0.37	0.00
Urban	8.94	0.38	7.46	0.30	0.80	0.00
TOTAL	13.49	0.62	11.40	0.30	1.17	0.00

APPENDIX F—ELECTRICITY GENERATION

Because electricity is consumed to a significant extent in all end-use sectors except for transportation, the CO_2 emission rate of electricity generation—grams of CO_2 emitted per kWh of secondary energy consumed—plays a determining role in the province's overall emissions.

Electricity generation accounted for about 20 percent of the Ontario's CO_2 emissions in 1988, mostly produced by Ontario Hydro's coal fired plants, which typically supply 50-75 percent of the province's peak energy demand. Coal fired power overall accounted for about 25 percent of the electricity consumed in the province in 1988. The CO_2 emission rate for secondary energy demand was 252 grams/kWh or .069 Mt/PJ in 1988.

The Ministry of Energy forecasts electricity demand will rise 55 percent from 1988 to 2005, compared with a 24 percent rise in overall secondary energy demand. Since much of the new demand, in the Ministry's projections, will be met by new hydro, nuclear, and natural gas cogeneration capacity, the role of coal in the fuel mix will diminish by 2005, causing the CO_2 emissions rate of electricity generation to fall more than half to 121 g/kWh or .03 Mt/PJ.

As a result of the measures outlined in Appendices B-E, however, provincial electricity demand increases from 465 PJ in 1988 to 609 PJ in 2005, an increase of 31 percent (see Table F-1). The calculation of energy use in 1988 does not include the "other" category in the commercial sector, which is not covered by the report's analysis, but the "other" category is included in the estimate for 2005. The calculation for 2005 was made by assuming the "other" category accounts for the same proportion of energy use in 2005 as in the Ministry of Energy's 1988 inventory. Hence, the total energy demand in 2005 would be about 609 PJ, which is used as the basis for the fuel mix described in Table F-2.

Table F-1:Change In Electricity Demand, 1988-2005

	1988 PJ	1988* PJ	2005 PJ	2005* PJ	Change %
Residential	153.47	167.27	113.94	123 97	-26%
Commercial	95.04	103.59	164.95	179.46	74%
Transportation	1.30	1.42	2.30	2.50	77%
Industry	177.00	192.91	278.92	303.46	57%
Sub-total	426.81	465.18	560.11	609.40	31%
Own uses/losses	38.37	0.00	49.29	0.00	
Total	465.18	465.18	609.40	609.40	31%

*In this column own uses/losses are factored proportionately into each sector.

The implications for the fuel mix and CO_2 emission rate in 2005 are significant. Assuming Ontario Hydro proceeds with the purchase of of electricity from Manitoba and the economic potential of 3,800 MW of new parallel generation is reached, there is no need for new nuclear units beyond Darlington A, other new non-fossil capacity, or new natural gas-fired combustion turbine units. Furthermore, the need for coal-fired generation is reduced from 73 PJ (in the Ministry's projections) to 41 PJ. Coal-fired generation declines from about 25 percent of the province's total generation mix in 1988 to seven percent in 2005. Under this scenario, the Manitoba purchase, natural gas parallel generation, and new hydraulic, such as upgrading the station at Niagara Falls, meets increased demand, displacing coal-fired generation. As a result, electricity's CO_2 emission rate declines to 90 g/kWh or .025 Mt/PJ.*This rate is used to calculate 2005 CO_2 emissions from electricity in Appendices B-E.*

Table F-2: Electricity Forecast, Fuel Mix and CO_2 Emissions, 2005

	MW	Cap-acity factor	Output GWh	Output PJ	Con-version efficiency	Input PJ	CO2 MT
Manitoba Purchase	1000	80%	7008	25 23	34%	73 57	0.00
Non-utility generation			33312	119 92	55%	219	8 68
Existing parallel:			5574	20 07	42%	48	0 71
hydraulic			3345	12 04	34%	35.12	0 00
coal			197	0 71	34%	2.09	0 19
oil			160	0.58	34%	1.69	0 13
natural gas			1727	6 22	80%	7.77	0.38
other			145	0.52	34%	1.54	0.00
New parallel:			27738	99.86	59%	170	7.97
hydraulic	200	50%	876	3.15	34%	9.20	0.00
natural gas cogen	3833	80%	26862	96.70	60%	161.17	7.97
Ontario Hydro			128944	464	34%	1352	5.26
Existing nuclear	12402	68%	73333	264 00	34%	769.90	0.00
Darlington A units	1762	80%	12348	44 45	34%	129.64	0.00
Hydraulic old + new	7596	56%	37263	134 15	34%	391 21	0.00
Coal:			6000	21.60	35%	61.71	5 26
Pulverized coal			5000	18.00	35%	51 43	4.75
Natural gas co-firing			1000	3 60	35%	10.29	0.51
TOTALS			169264	609	37%	1645	13.94

Natural gas is assumed to be co-fired with pulverized coal, replacing 20 percent of the coal on an energy basis. A "clean coal retrofit technology" developed in the United States by the Gas Research Institute and now reaching commercialization, natural gas co-firing not only lowers CO_2 emissions but sulphur dioxide emissions as well, by 20-30 percent. Co-firing would allow an extra margin of safety under the province's acid rain pact with Ontario Hydro.

Given the estimates in Table F-2, a total of 29,000 GWh of nuclear and coal capacity would be available for Ontario Hydro's "reserve margin", about 18 percent of the total. While this falls within the range accepted among U.S.utilities for adequate reserve, it falls short of Ontario Hydro's assumption concerning its need for a 24 percent reserve margin in its Demand-Supply Plan. Meeting that target would require another 10,000 GWh of capacity, requiring about 1,500 MW operating at 80 percent capacity. Such capacity could be met by additional load following parallel generation. The technical potential exists, and higher buy-back rates would no doubt make such potential more economic. If developed, Ontario Hydro's coal stations could be put in reserve, thus reducing the CO_2 emission rate of electricity even further.

The electricity forecast for 2005 would not look much different were the government solely trying to achieve the goals of the nuclear moratorium by eliminating need for new nuclear capacity beyond the new Darlington B units. Ontario Hydro might opt for less new parallel generation and new combustion turbine units. Reliance on coal-fired stations might be greater, and the co-firing option would probably not be explored at these sites. Achieving reductions in CO_2, however, compels an even more assertive effort to realize the economic potential of parallel generation than might be required only under the nuclear moratorium. One additional benefit to CO_2 reduction would be the avoidance of billions in dollars of capital costs to install scrubbers to control acid gas emissions from coal-fired power stations. Retrofitting co-firing technology on coal boilers would require less capital investment, than scrubbers.